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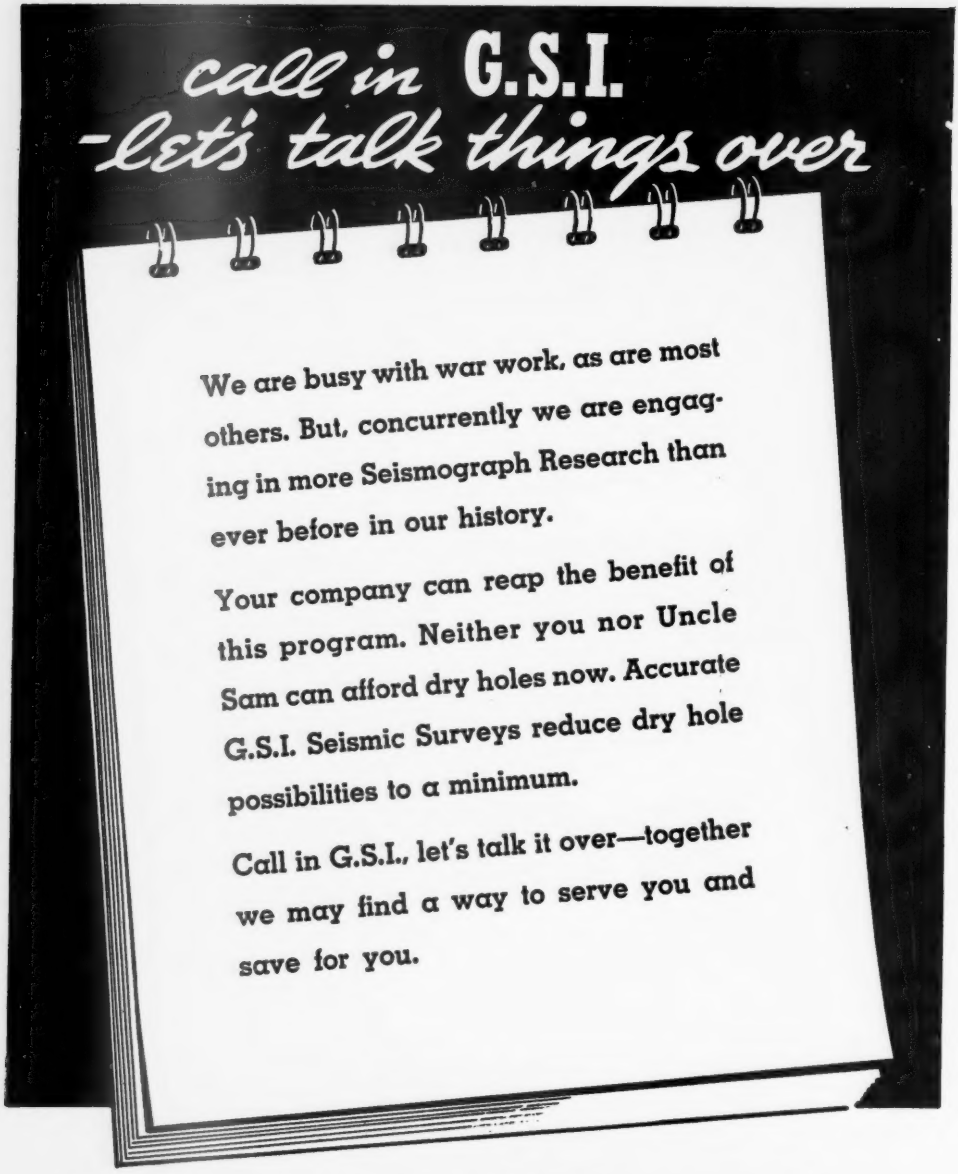
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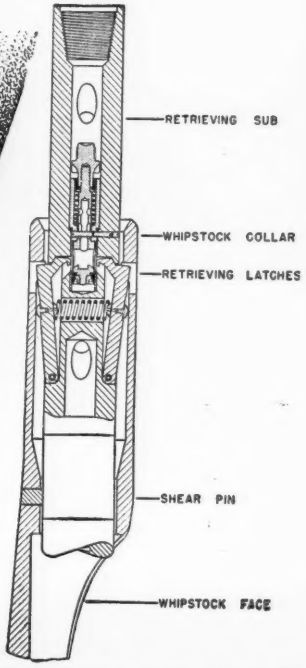

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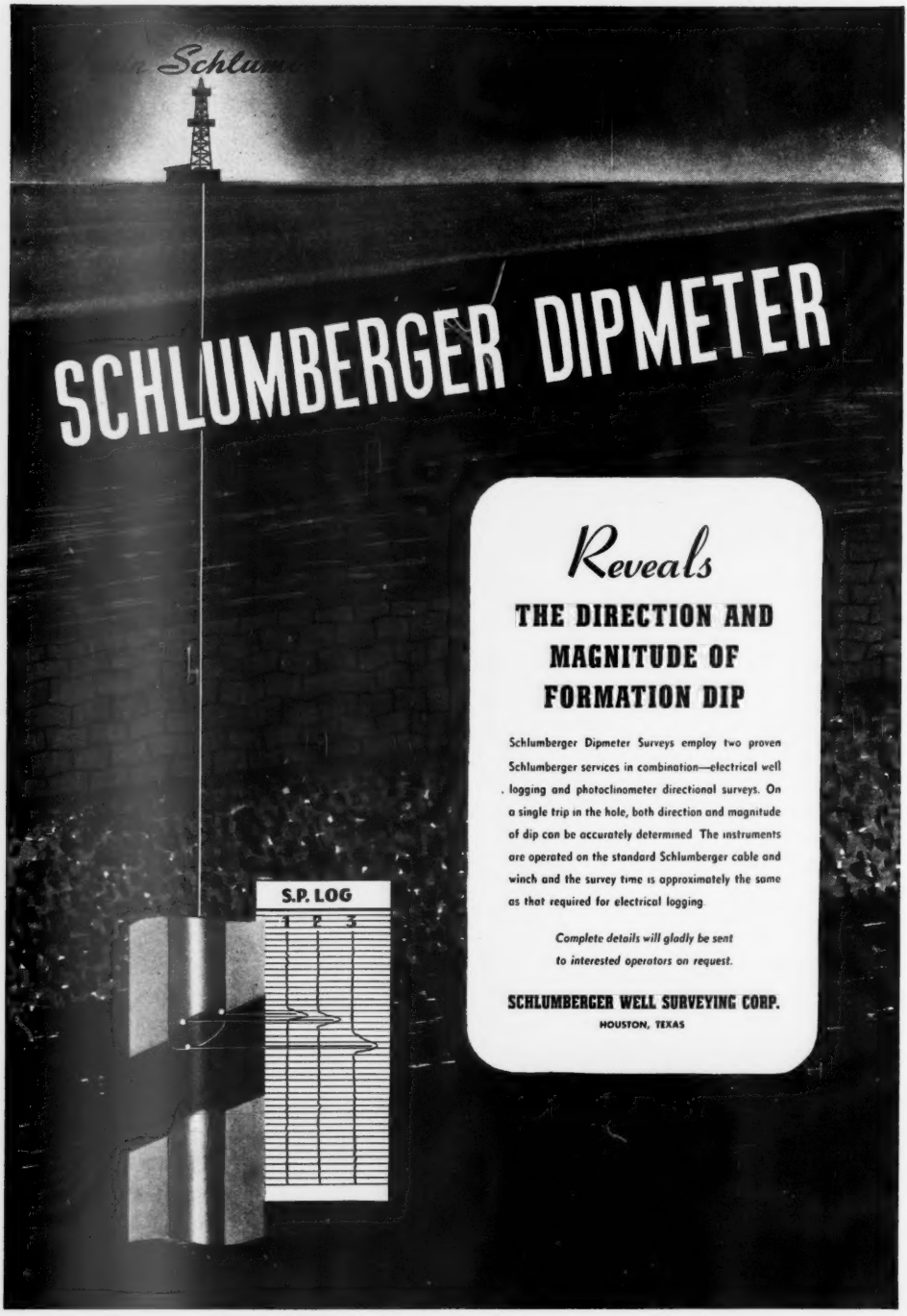
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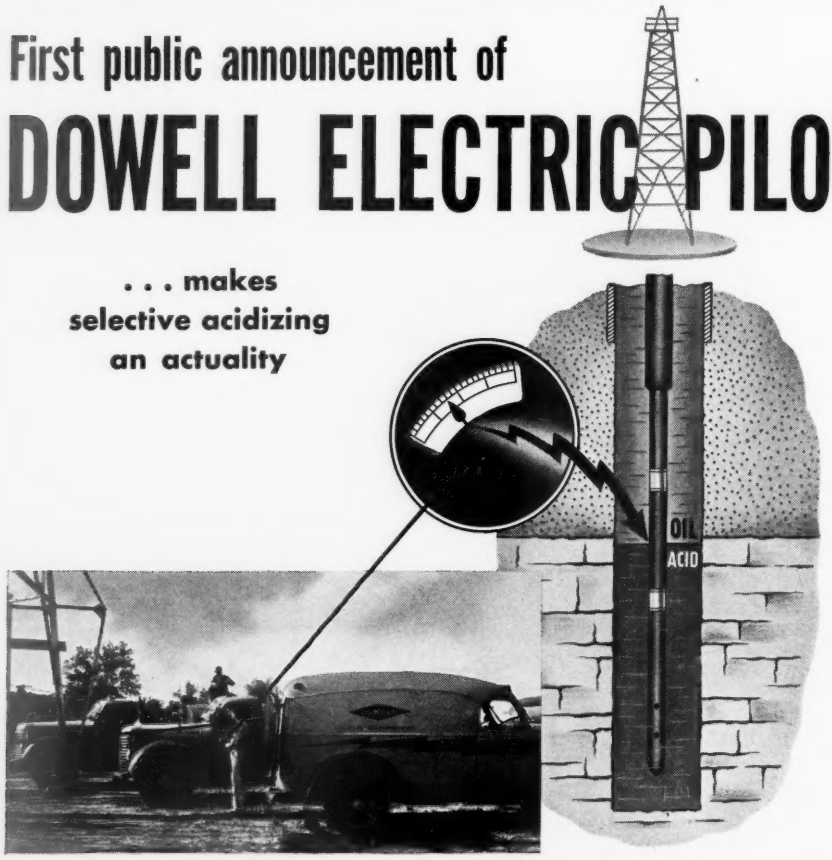

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Volume 26 Number 12

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

DECEMBER, 1942

DEVELOPMENT AND USE OF ENGINEERING GEOLOGY

FOREWORD

PAUL WEAVER, FRITZ L. AURIN, EDGAR W. OWEN, EDMOND O. MARKHAM, AND WALTER A. VER WIEBE

The petroleum geologist is learning from the detailed correlation of wells in oil fields that there are so-called minor faults on many producing structures which, although of small throw, are important in their effect on oil accumulation and reservoir performance. He has also observed that the hade and direction of the fault planes seem to depend upon the kind of rock which has been faulted. He has usually not enough data available from wells to be able to map the faults completely, or to be sure every fault on the structure has been mapped, but he has enough experience during recent years to know that smooth, unbroken, subsurface contour maps are probably only a generalization of, and an approximation to, the actual structure.

In the article which follows, it is shown that detailed mapping of geology of dam sites shows that the response of different rock formations to faulting and loading is significantly different, and also that a faulted area can be expected to consist of a great number of individual faults; here again, as in oil fields, smooth, unbroken contours do not represent the situation correctly.

The author has also emphasized the responsibility which the geologist must assume, jointly with the construction engineer, in planning the safety of these dams, which, of course, are located primarily because the topography of the stream valley will provide adequate reservoir storage, and not because the geological conditions are ideal for foundations. Engineering projects of other kinds, such as water supplies, roads, and gun-emplacements, are also demanded at certain sites selected for military reasons, and the geologist and construction engineer are called upon to make plans for those locations. So it is very timely that all geologists study the problems involved in working under limitations of this kind, to be prepared to help in the war effort.

The examples cited in detail by the author are among the greatest dam-site projects of all time, and this article will be an outstanding geological reference as the years to come bring to fruition the utilization of the supplementary public

works to distribute the waters stored by these dams. The clarity of the figured discussion of the geology at each locality is noteworthy and will be instructive to our membership as an aid in preparation for similar reports. We should be prepared to furnish these as a public service when we are called upon to contribute data obtained as a by-product of geological mapping for petroleum, or when we have a specific assignment to collect data especially for such projects.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 12 (DECEMBER, 1942), PP. 1797-1826, 14 FIGS.

DEVELOPMENT AND USE OF ENGINEERING GEOLOGY[1]

F. A. NICKELL[2]
Whittier, California

ABSTRACT

The engineer is forced to consider early in the study of new projects what effect natural conditions will have on costs and ultimate success of construction. Gradually, he has realized in geology a way to anticipate and understand these conditions. Appreciation was not instantaneous, for it has required at least 35 years to arrive at the present status.

The engineering geologist is primarily concerned with the occurrence and physical character of rocks, ordinarily at relatively shallow depths. His work in obtaining necessary information revolves more around questions of feasibility and security than matters of economic justification.

The investigation and construction of Boulder, Grand Coulee, Shasta, Friant, and Marshall Ford dams present a wide variety of problems. These are, according to volume, the five largest concrete dams in the world.

INTRODUCTION

Careful control of materials determined by standards based on laboratory research and proved methods of construction gives the engineer reasonable assurance that soundly designed structures will perform according to expectation. He is compelled, however, to add a "factor of safety" in judgment on the response of rocks and foundations that can not be reliably analyzed in every case. These factors become increasingly important in proportion to the size of structure.

Gradual acceptance of the value of geology in orderly planning of new projects is evident. This growth is displacing a concept that significant geological conditions of an area will be clearly seen by experienced locating engineers or can be surmounted by selected methods of construction.

The transition has been a slow process. Perhaps it began with William Smith[3] (1769–1839), regarded as the "Father of English geology." He started professionally as a civil engineer and was diverted to geology by an interest in nature. In this country a later example is offered in the case of Homer Hamlin, first engaged in geology, then in engineering for large California municipalities. Ultimately, in studies on control of the Colorado River, he became one of the first engineering geologists. A large-scale conversion is indicated in the history of the Bureau of Reclamation from the hydrologic branch of the Geological Survey.

A milestone was the appointment of J. F. Kemp, C. P. Berkey, and W. O. Crosby as consultants during the investigation and construction of the Catskill Water Supply Project[4] of New York. This is the first instance, or one of the earliest instances, of geologists with a major engineering project.

Next came the occasional employment of men from universities and State or Federal surveys for preliminary studies and phases of construction. Those in this group usually were prominent in other geological fields. C. P. Berkey, Kirk Bryan,

[1] Manuscript received, July 25, 1942. Published by permission of the Commissioner, Bureau of Reclamation.

[2] 116 Berkeley Way. Formerly head geologist, Bureau of Reclamation.

[3] Archibald Geikie, *The Founders of Geology*, pp. 381–96. Macmillan and Company (1905).

[4] C. P. Berkey and J. F. Sanborn, "Engineering Geology of the Catskill Water Supply," *Proc. American Soc. Civil Engineers*, Vol. 48 (1922).

W. J. Mead, G. D. Louderback, A. C. Lawson, and F. L. Ransome are outstanding among them. They operate without notable distinction from the strictly professional engineering geologist, as Hyde Forbes and I. B. Crosby, engaged in general practice.

Large engineering concerns maintain a regular staff. These organizations are principally governmental divisions having construction programs that warrant continuous employment. Among them are the United States Engineers, Tennessee Valley Authority, and the Bureau of Reclamation of the Federal agencies, public works divisions of certain states operating under laws requiring supervision of construction where public welfare is involved, and many municipalities with plans for flood control and procurement of domestic water supplies. A few private companies, chiefly in fields of transportation and public utility, have one or more geologists but the majority depend upon consultants.

SOURCES OF INFORMATION

The treatment of subject matter has been inadequate both for the needs of engineers interested in conditions they recognize, and for the geologist desirous of comparing similar problems. Text books are usually too general for suitable application to the point in question. Articles of probable value are difficult to find without a bibliography.

The suggestion was made recently that provision should be made for a separate publication on engineering geology. Justification is not indifference of technical journals, for they freely accept manuscripts conforming to editorial policies. The trouble in part arises through the wish of geologists to give expression in engineering journals, or their failure to publish topics of interest for future reference.

The appendix of an excellent book[5] illustrates where source data can be obtained. The ratio of articles is about 4 to 1 of those contained in engineering journals to the number in geological publications. A greater disparity would be indicated if water-supply bulletins were omitted.

DUTIES OF ENGINEERING GEOLOGIST

The relationship of the geologist to the engineer, essentially in an advisory capacity, has been discussed in considerable detail.[6] This is basically the same for other fields because decisions of the geologist normally are subject to economic restrictions, company policy, and coördination with different activities of the organization.

The engineering geologist, contrasted with the economic geologist, is principally concerned with the physical character of rocks, particularly those at a relatively shallow depth. There is an immediate and equivalent test of judgment in construction, as in any other line of geological endeavor, in view of the

[5] R. F. Leggett, *Geology and Engineering*. McGraw-Hill Book Company (1939).

[6] "Symposium on Geology and Engineering," *Amer. Inst. Min. Met. Eng. Tech. Pub. 215* (1929).

necessarily close adjustment between design and actual conditions. Costs mount rapidly with slight modification of excavation or special treatment of an unsuspected feature.

There are other channels of service for the engineering geologist besides construction. Development of water resources involving ground-water studies is allied to the field of hydrology. Investigation of construction materials in manufacture of cement or production of building stone has a tie with the economic geologist as well as with the materials engineer.

The matters of interest are fairly well defined. Subjects are considered approximately in the following order.

1. Regional and local geology, including seismicity
2. Character, sequence, and structure of formations at the selected site
3. Thickness of superficial cover, or, the depth of overburden to be removed to reach suitable rock
4. Physical limitations of rock if a structure or tunnel is to be built; stability under load
5. Detailed features of foundation indicating requirements for special treatment
6. In case of water-conservation projects, a determination of seepage effects
7. Availability of construction materials

Several of the listed items can be interpreted quantitatively by means of field and laboratory tests. The value of conclusions depends on the basic engineering knowledge of the geologist and on an elementary understanding of geology by the engineer.

The geologist in an organization of engineers is relieved largely of decision on questions of economic feasibility. This differs notably, for example, from the obligation of the petroleum geologist, who must weigh probable success against failure or expected return against development costs.

The engineering geologist shares a distinguishing responsibility with engineers in regard to safety of structures. Most of the outstanding projects, particularly large storage dams, directly concern matters of public security. The measure of geological responsibility can not be stated precisely. A list of 305 dam failures shows that approximately 20 per cent of this number resulted from conditions attributed to defective foundations. In this instance the geologist has arithmetically one-fifth the responsibility of the engineer. Actually, he is wholly to blame in cases where poor judgment was exercised without protest.

EXPLORATORY METHODS

The need for accurate information is repeatedly emphasized. Standard methods providing quantitative data are widely adopted in most fields of exploration. These are briefly compared.

DRILLS

The rotary diamond drill is marketed in various sizes, with means of operation adapted to requirements. The popular skid-mounted, gasoline-driven rig with jointed rods, detachable bit and core barrel is an extremely useful prospecting tool. Small-diameter holes can be put down to depths of several hundred feet. Its advantages are rapid progress, maneuverability, reliable sampling in all except the poorest rock, and holes that can be readily tested for percolation.

Cost is dependent on volume of work, nature of formations, size of hole, and character of specific tests. It varies ordinarily between $2 and $10 per foot and can be estimated satisfactorily at about $4.

The calyx (shot) drill is used where observation of undisturbed rock in place is desired. Holes up to 3 feet in diameter are generally drilled on engineering projects, enabling periscopic or visual examination underground. Progress is relatively slow and depths are commonly limited to less than 100 feet. Proportionately higher costs result, ranging from about $10 to $25 per foot.

Sampling of unconsolidated deposits is erratic, particularly as to physical state of the formation in place. Cable, percussion drills or the diamond drill operated for wash boring by means of a chopping bit are available for this purpose. The return water or sludge shows the nature of beds penetrated. Removal of the "fines" tends to distort the concept of range in particle size. Drive samples obtained by forcing material into a core barrel ordinarily are disturbed. A sampler recently designed for the rotary rig is proving successful when the material is somewhat bonded. Percolation tests are doubtful because the side of the hole becomes coated.

The cost of wash boring depends on the extent of the program, nature of materials, amount of casing required, *et cetera*. Some concerns will contract drilling of wells for a figure as low as 60 cents per foot. Experience, on investigation, indicates the usual cost is about $2.50 per foot.

GEOPHYSICAL SURVEYS

By virtue of analogy between theory and physical constants of rock, methods of geophysical surveys promise more than a means to determine structure and sequence of formations. The electrical-resistivity equipment and the refraction seismograph are finding increasing use both for preliminary and supplemental engineering investigations. It is unlikely, however, that any geophysical device will entirely displace operations wherein actual samples can be recovered.

The seismograph has considerable appeal along research lines in stability (periodicity) analyses of foundations and buildings. It can be adapted with refinements for measuring deterioration of concrete by relationship of seismic velocities to modulus of elasticity. Operating costs of a small seismograph party are approximately $50 per day.

OTHER MEANS OF EXPLORATION

The direction and amount of seepage are factors influencing feasibility of water-conservation projects. Comparative data can be obtained from pressure tests in drill holes where leaky zones are segregated by hydraulic or mechanical packers. The rate of movement between holes or to points of escape can be established under favorable conditions with a tracing fluid or electrolyte.

The engineer has a high regard for the materials laboratory. Procedures have been developed to evaluate the modulus of elasticity, compression and shear

strengths, size range by sieve analysis and permeability. Knowledge of physical constants for rock types is necessary to the engineering geologist in his examination of prospective sites.

Tests on unconfined samples give results that do not apply strictly to rock in place, particularly in the range of maximum values. It is possible by field procedure to simulate laboratory experiments on compressive strength through bearing tests conducted with a hydraulic jack or loaded column. Care has to be taken to eliminate instrumental error.

Pits, shafts, and exploratory tunnels are required for investigation of materials and examination of conditions shown by drilling. Cost is influenced by depth, amount of timbering, character of formations, volume of ground water or drainage, and available equipment. Pits in unconsolidated alluvium will run between $2.50 and $4 per foot on the average, up to approximately $10 per foot when timbered and deep. Shafts and tunnels are too short usually for economical mining. Costs for them range from $4 to $25 per foot, according to dimensions and other conditions.

Adequate petrographic equipment for geological studies is available in most large organizations. The study of geological problems may be coördinated with research on construction materials.

APPLICATION OF ENGINEERING GEOLOGY

Similarity as well as contrast is seen in comparison of projects. Notwithstanding this fact, large dams involve a sufficient variety to illustrate problems of engineering geology. Boulder, Grande Coulee, Shasta, Friant, and Marshall Ford, recently completed or under construction, will be[7] the five largest (volume) concrete dams in the world (Fig. 1). They are key structures having a multiple purpose, and they combine stream control, power development, and conservation of water for irrigation.

BOULDER DAM

Colorado River, a heavy silt carrier, fluctuates widely between low water and flood stages. Irrigation by canal to land in Lower California (Mexico) and Imperial Valley formerly depended on continued maintenance of the distribution system and demanded large annual expenditures for removal of deposited silt.

Boulder Dam,[8] near Las Vegas, Nevada, is an arch-gravity design. It stands 727 feet (crest elevation, 1,232) above the lowest point in the foundation and forms a reservoir, Lake Mead, reaching 115 miles upstream nearly to the Grand Canyon. The storage capacity of the reservoir is 31,000,000 acre-feet. Work on the dam was begun in 1931 and was finished in 1935.

[7] Data obtained from files, Bureau of Reclamation, Washington, D. C., April 1, 1941.

[8] P. A. Kinzie, I. A. Winter, and L. N. McClellan, series of articles appearing in *Engineering* (1937–38).

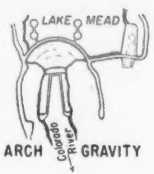
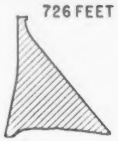
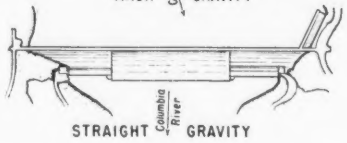
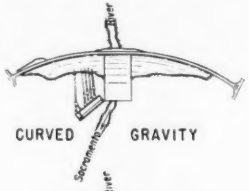
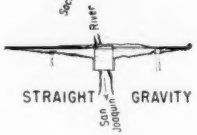
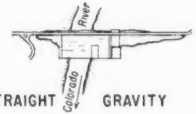
FEATURE	TYPE OF STRUCTURE	MAX. HEIGHT	CREST LENGTH	VOLUME OF CONCRETE	YEARS UNDER CONSTRUCTION	MAX. NUMBER MEN EMPLOYED	APPROX. COST
BOULDER DAM ARIZONA-NEVADA			1,282 FEET		5	5,218	$ 78,000,000
GRAND COULEE DAM WASHINGTON			4,200 FEET		7	7,700	$ 111,000,000
SHASTA DAM CALIFORNIA			3,500 FEET (EMBANKMENT NOT SHOWN)		5 APPROX.	2,461 TO DATE	$ 78,500,000
FRIANT DAM CALIFORNIA			3,430 FEET		4	1,532	$ 20,000,000
MARSHALL FORD DAM TEXAS			2,700 FEET (EARTH EMBANKMENT 4,100 FEET NOT SHOWN)		5	1,101	$ 23,000,000

FIG. 1 – COMPARATIVE DATA ON THE WORLDS LARGEST (VOLUME) CONCRETE DAMS

GENERAL GEOLOGY

The head of the reservoir is in the plateau region of northern Arizona. Most of the project,[9] however, is in the "basin-and-range" physiographic province characterized by northward trending mountains separated by broad structural basins where the greater portion of the storage is obtained.

Pre-Cambrian rocks of the Lower Granite Gorge underlie Paleozoic formations of the plateau. At Grand Wash Cliffs the series is displaced by strong faulting as the stream emerges from a northwesterly course in the canyon. It reappears in part in the canyons farther south, where the river cuts through uplifted blocks of hard rock (Fig. 2). The intervening depressions contain Tertiary or later land-laid sediments and lava. This picture is repeated variously to the delta at the Gulf of Lower California.

Preliminary studies were made of alternative sites in Boulder Canyon (granite, *et cetera*) and Black Canyon, where the dam is located, 15 miles downstream. Investigation by means of drill holes in the channel with prospect tunnels into the lower abutments defined the amount of overburden and the character of materials at depth.

Black Mountains range, east of the river, continues for 50 miles from Boulder Canyon. The pre-Cambrian series at the northern end passes beneath Tertiary lava that composes the entire southern portion of the range. The volcanic rocks occur at lower levels west of this divide and enclose Black Canyon, with Boulder Dam near the entrance.

The major topographic features of the region, modified by erosion, are clearly resultant of differential faulting on a large scale. Tilted Quaternary deposits of the river in places are offset, indicative of geologically recent movement. No evidence of present surface disturbance is found, from which it is concluded the faults now are inactive.

The occurrence of saline beds of continental origin (Muddy Creek formation, Pliocene?) within the major basins of the reservoir and downstream from Black Canyon indicates that the river as an integrated drainage system came into existence not before late Tertiary time at the earliest.

LOCAL GEOLOGY

The upper part of Black Canyon and neighboring areas adjoining the dam site were mapped by F. L. Ransome (Fig. 3). The formations are separated into two groups. The Older Volcanic series, containing dark andesitic flows, breccias, and intrusive masses, appears downstream from the site. A Younger Volcanic series including latites, sediments, much basalt (trachydolerite), and various dikes and sills, overlies this earlier sequence and extends from the dam site to the head of the gorge. Between these major divisions is a crudely stratified horizon of andesitic tuff breccia, called, for convenience of identification, Dam Breccia, on which the structure rests. The entire section is essentially a continuous record

[9] C. R. Longwell, "Geology of the Boulder Reservoir Floor, Arizona-Nevada," *Bull. Geol. Soc. America*, Vol. 47 (1936).

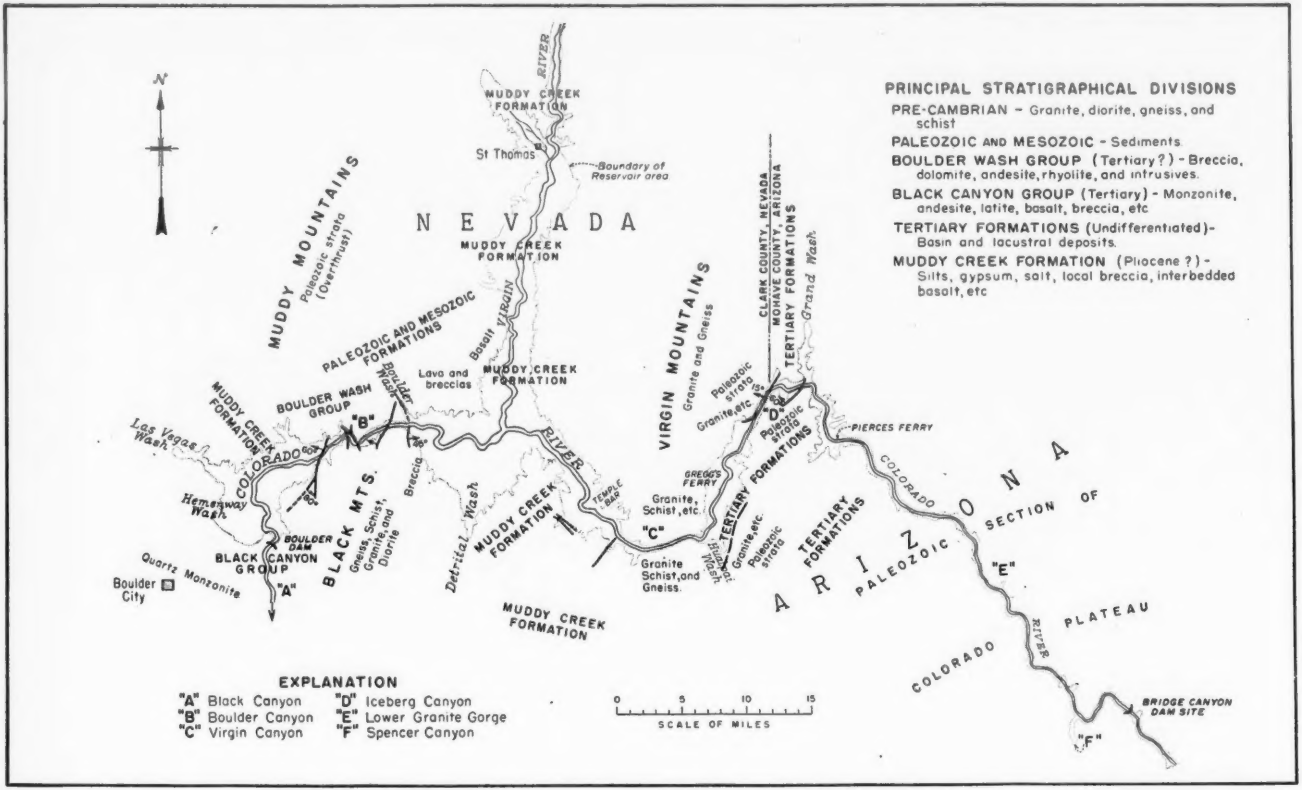
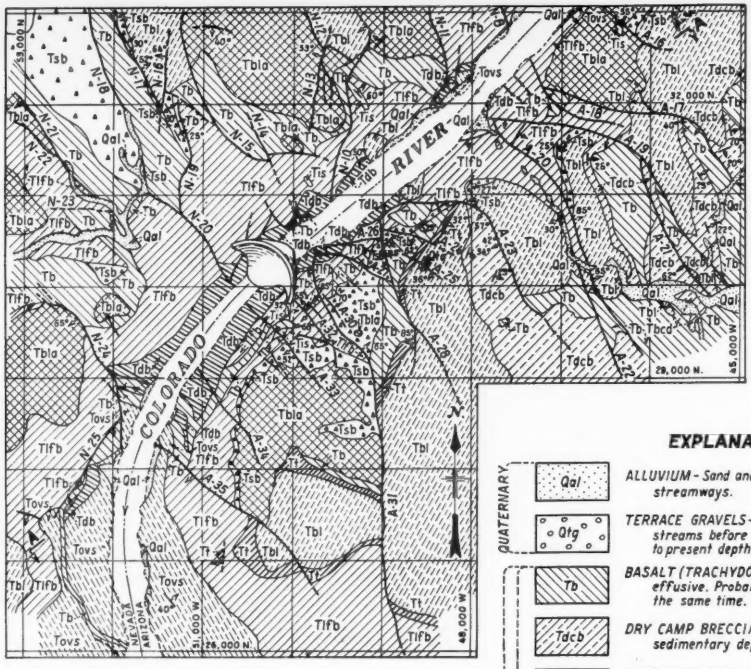


FIG. 2 - LOCATION MAP OF BOULDER DAM AND RESERVOIR, LAKE MEAD



Geology modified after F L Ransome-1931

200 0 800 1600
SCALE OF FEET

NOTES

The more important faults are numbered consecutively downstream on each side of the river. The prefixed letters N and A signify Nevada and Arizona respectively.
Low water elevation of river at damsite is 645.

EXPLANATION

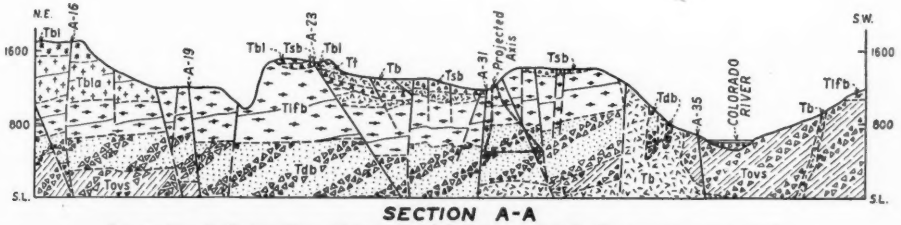
QUATERNARY

- Qal — *ALLUVIUM - Sand and gravel of present streamways.*
- Qtg — *TERRACE GRAVELS - Gravels deposited by streams before canyon of river was cut to present depth. Of at least two ages.*

PROBABLY EARLY TO MIDDLE TERTIARY — YOUNGER VOLCANIC SERIES

- Tb — *BASALT (TRACHYDOLERITE) - Intrusive and effusive. Probably not all erupted at the same time.*
- Tdcb — *DRY CAMP BRECCIA - An inter-volcanic sedimentary deposit.*
- Tbl — *BIOTITE LATITE - Thick and extensive lava-flows; also occurs as sills and intrusive masses.*
- Tf — *TUFF - A soft grey or yellow sedimentary rock composed of small particles of glassy lava, chiefly biotite latite.*
- Tbla — *BASIC LATITE - Dark lava-flows with perhaps minor intrusive masses.*
- Tsb — *SPILLWAY BRECCIA - An inter-volcanic sedimentary deposit of very variable character.*
- Tlfb — *LATITE FLOW-BRECCIA - Mainly lava-flows but inclusive of some probably intrusive matter.*
- Tis — *ISOLATED BODIES OF SEDIMENTS IN LAVAS - Chiefly reddish sandstone and breccia.*
- Tdb — *DAM BRECCIA - Reddish sedimentary deposit, composed largely of fragments of monzonitic porphyries.*
- Tovs — *OLDER VOLCANIC SERIES - Mainly dark andesitic or latitic lava-flows with some breccias and intrusives.*

FAULT



SECTION A-A

Representing idealized position and sequence of formations. Most faults, appearing as normal faults, have a considerable strike-slip component of movement.

FIG. 3 - Map and section showing formations and geological structures in vicinity of BOULDER DAM

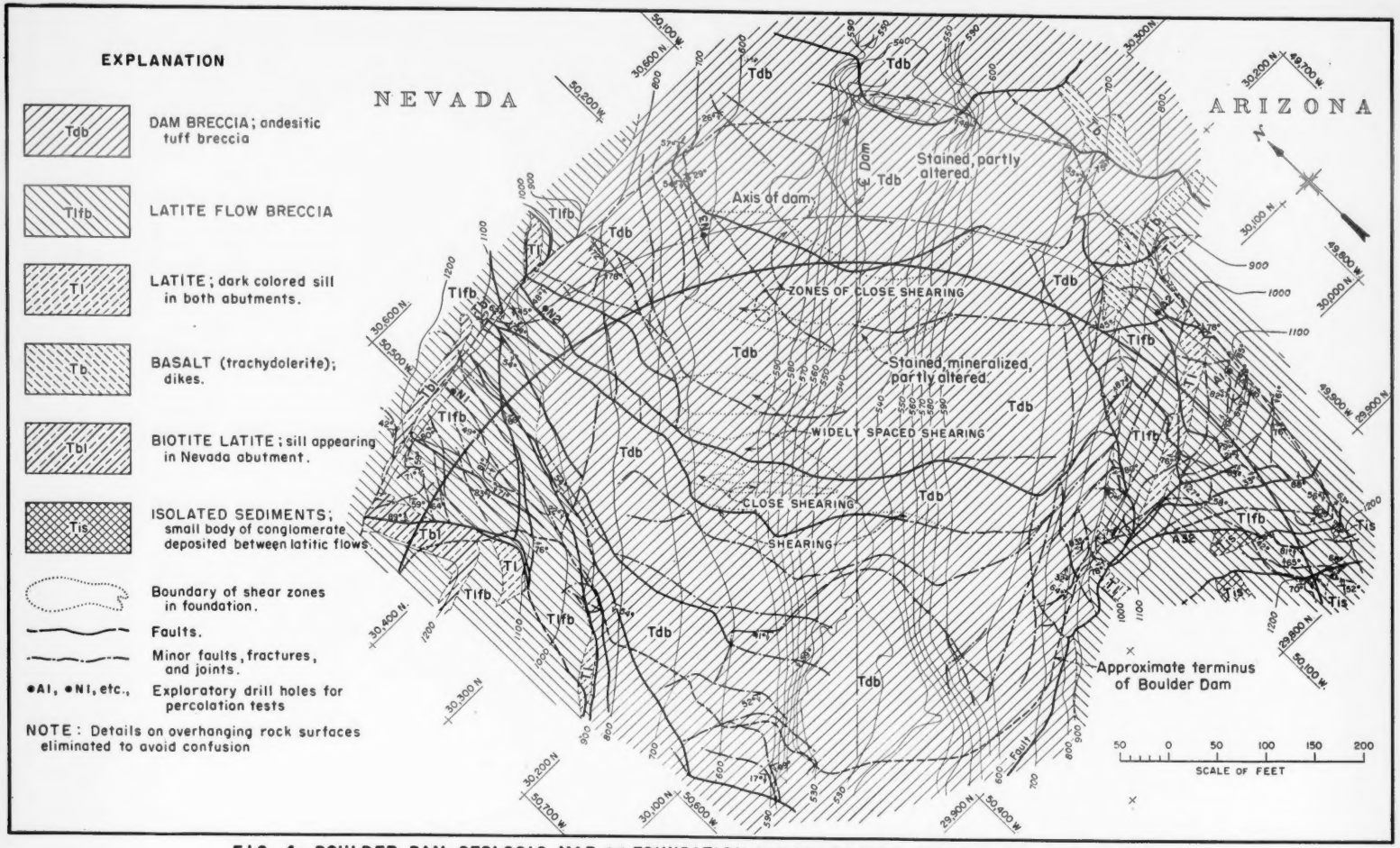


FIG. 4 - BOULDER DAM - GEOLOGIC MAP OF FOUNDATION AND ABUTMENTS AFTER FINAL EXCAVATION
(LOOKING UPSTREAM TOWARDS RESERVOIR)

of outburst and erosion in middle or early Tertiary time. Source vents were evidently scattered but are in part concentrated in an area 4 miles downstream near the contact with pre-Cambrian rocks.

The formations dip persistently on the average 30° N.E., upstream (Fig. 3). A large number of minor faults with vertical displacement amounting rarely to 200 feet cross the canyon at right angles. Cemented breccia and one example of accordant pot-hole structure on opposite sides of a zone testify to the absence of movement perhaps during the period of canyon cutting. Fluting of wall rock reflects a strong horizontal (strike-slip) component. The faults otherwise appear to be normal faults with throw ordinarily marked by dropping of the downstream (south) block.

FOUNDATION FEATURES

The final location, selected on the basis of the massive character of the rock and comparative freedom from structural complications, takes advantage of the most favorable distribution of formations. Dam Breccia, one of the best rocks in Black Canyon, occupies the floor and lower half of the abutments. According to compression tests in the laboratory on 16 core samples, the Dam Breccia has an average ultimate strength of 15,920 pounds per square inch (minimum, 9,260; maximum, 22,400). The upper portion of the abutments is chiefly in latite flow-breccia which is able to carry reduced stresses in the higher section of the dam with a sufficient factor of safety.

The detailed structural pattern (Fig. 4) is formed by many joints and a few minor faults bordering the excavated area. These introduce no problems with respect to load for the weight is distributed across small fractures. Influence on seepage has been noted in progressive operations on grouting and drainage.

The outline of bedrock is unusual. The floor is equally divided between benches (elevation, 600 feet) on each side and an inner gorge (elevation, 520± feet). The trench does not correspond with any recognizable line of weakness and, judged from a repetition in other canyons along the Colorado River, must represent rejuvenation of the stream, perhaps at the end of the glacial period (Fig. 5).

A buried plank at elevation 595 feet marked the minimum depth of scour during recent floods (low-water elevation, 645). The maximum limit is unquestionably somewhat lower but the character of alluvial material does not define the ultimate reach. It is unlikely that even the largest floods completely swept the overburden from the bottom.

The reservoir presents a unique opportunity to study isostatic changes and differential adjustments between mountain (uplifted) and basin blocks under measured incremental loads over a definite area. Precise surveys, not released, disclose small settlement. Another item of interest to the geologist has been the revitalizing of faults through static forces of water load. The disturbances are poorly correlated with seasonal changes in reservoir level. Microseisms of maxi-

mum intensity of IV on the modified Mercalli scale (1931) are recorded. The loci are definitely established along known major fault zones marginal to depressed blocks a number of miles from the dam.

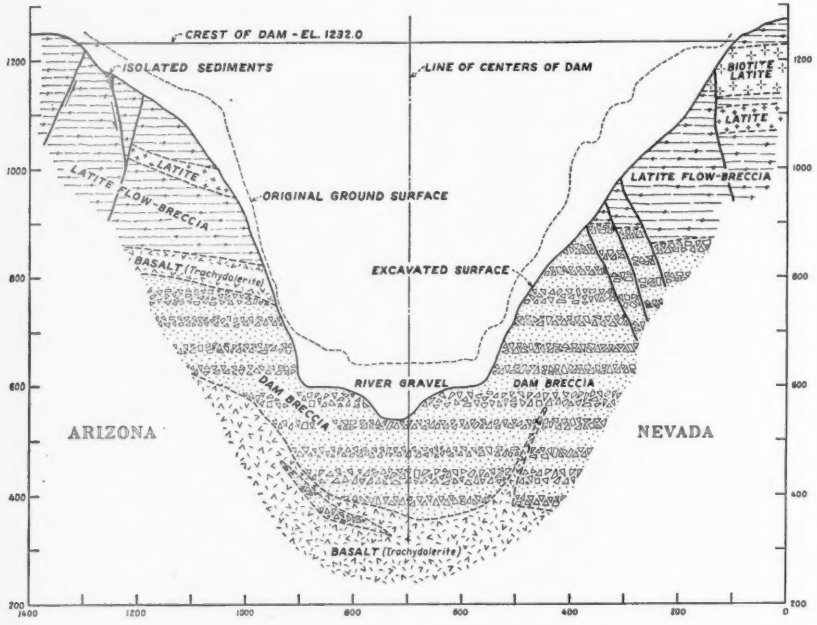


FIG. 5 - Profile section along axis (looking downstream), in part hypothetical, showing formational sequence of rocks in abutments and foundation for BOULDER DAM.

GRAND COULEE DAM, WASHINGTON

An enormous area of irrigable land lies within reach of the Columbia River in Washington. Most of this country is above elevations where direct diversion for irrigation is possible. Grand Coulee Dam, northwest of Spokane, was completed in 1941, seven years after work was started, at a site in the central eastern part of the state. This is a straight-gravity dam[10] reaching 550 feet above the lowest point uncovered in the foundation and containing nearly 10 million cubic yards of concrete (Fig. 1). Part of the power developed here will be utilized for pumping water from the reservoir into an extensive canal system.

GENERAL GEOLOGY

The Columbia River, rising in Canada, flows southward to the mouth of the Spokane River, then westward along a line somewhat north of the mid-section

[10] "Grand Coulee High Dam," *Engineering News-Record* (December 23, 1937), pp. 1021–24.

of Washington to a point approximately in the center of the state. From there it turns south or southeast to the Oregon boundary, where it again follows a westerly course to the Pacific Ocean.

The Columbia and Spokane rivers in one leg separate older crystalline rocks of northeastern Washington from Tertiary lavas and associated sedimentary formations occupying virtually all of the southern half of the state. At Grand Coulee Dam the Columbia River is running almost north between Jurassic granite (Colville batholith) on the east and Tertiary Columbia River basalts on the west.

During the Pleistocene, repeated advances of the Continental Ice Sheet southward obstructed the canyon. The river on those occasions was forced into other channels along the glacial front. Much of the water followed Grand Coulee in a westward direction, overflowing adjoining bench land in the manner of a sheet flood, returning to points along the valley downstream. Majestic erosional effects were produced such as enormous water falls over the receding margin of lava flows, deepened coulees along earlier drainage features, and large tracts of scab land where the lava is denuded of soil.[11]

LOCAL GEOLOGY

Three formations are concerned at the dam site. These are Jurassic granite in which the canyon is cut, Quaternary sediments of glacial and concurrent stream origin, and recent deposits of the river. The Tertiary lava and associated beds (Latah formation) do not extend into the area. The conditions appear to be less complex than ordinarily found at major dams.

The granite consists of two varieties, products of differentiation from the same source. The greater portion of the foundation rock is coarse-grained granite which has been invaded by thick dikes of fine-grained granite (Fig. 6). An occasional intrusion of basalt in the series is probably related to the Tertiary lavas.

The overburden includes varved clays resting on the rock floor and grading upward into sandy members, till, and stratified stream deposits. Wedges of this material on the sides became unstable after disappearance of the glaciers, as the rejuvenated river removed the valley fill. Old slump lines and fresh breaks resulted in persistent slides in places adjoining the excavation for the dam. Much effort was made to retain these masses. Success was finally achieved by a combination of three standard methods: elaborate drainage to reduce pore pressure and plasticity, unloading to decrease dead weight, and dumped rock along the toe for additional support and confinement.

The structural pattern is composed of small faults at broadly spaced intervals and three related systems of joints. The faults are more or less regional features for they make possible identification of granitic areas on aerial maps by orientation of subsequent erosion. The age of the faults can not be determined at the dam site; however, they are possibly connected with a period of crustal adjustment producing major folds of monoclinal character having a similar orienta-

[11] R. F. Flint and W. H. Irwin, "Glacial Geology of Grand Coulee Dam, Washington," *Bull. Geol. Soc. America*, Vol. 50 (1939), pp. 661–80.

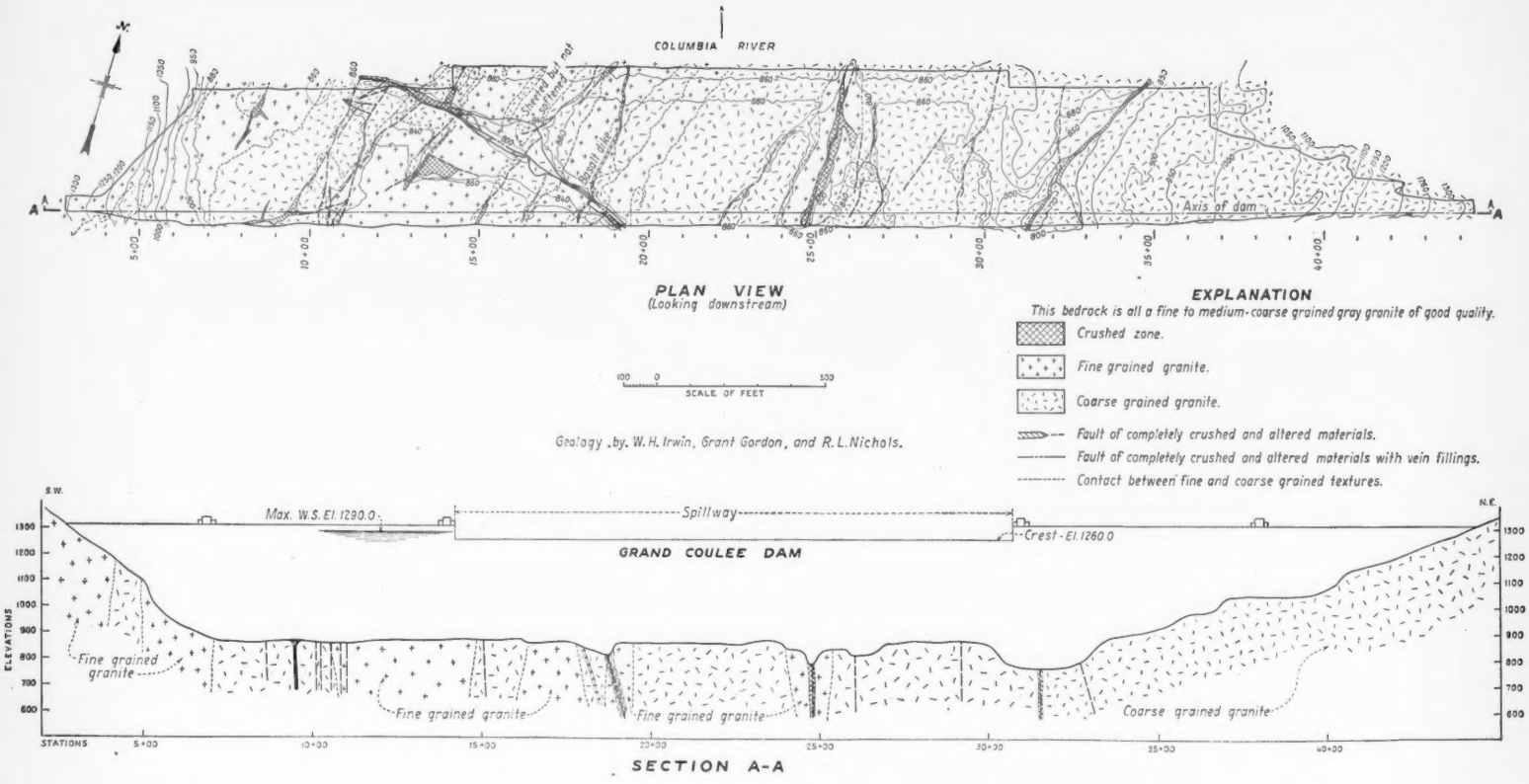
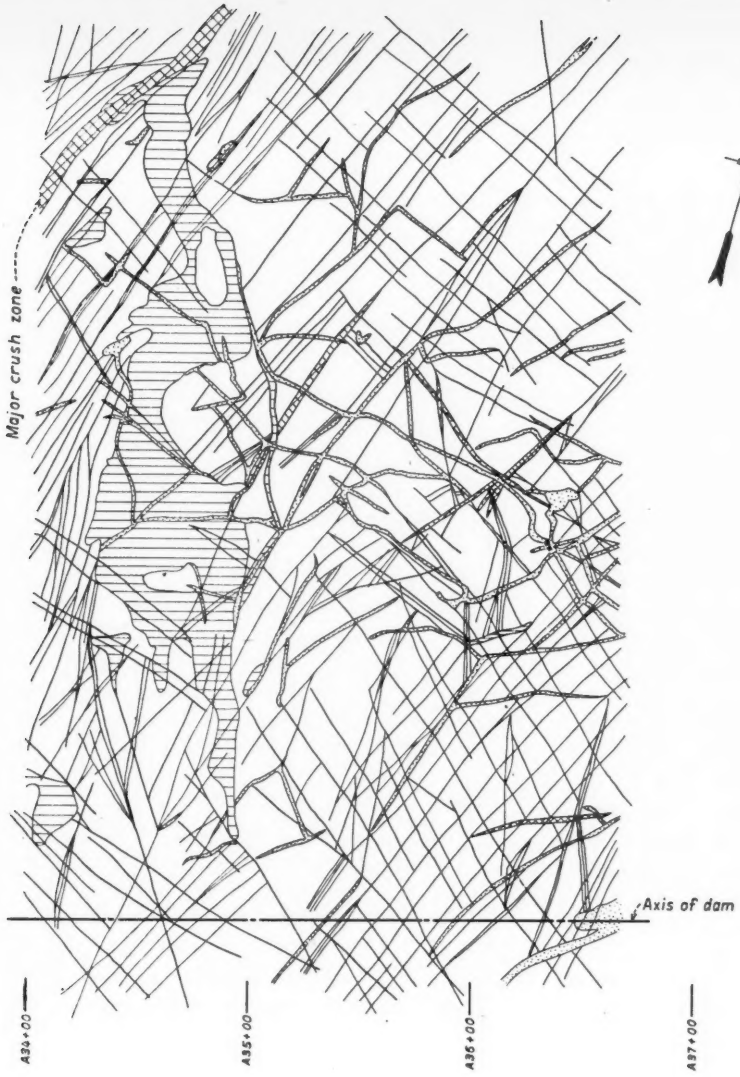


FIG. 6 - Plan and section showing principal structural features of excavated foundation for GRAND COULEE DAM



EXPLANATION

This bedrock is a fine to medium-coarse grained gray granite of good quality.

Pegmatite

Crushed and altered zone.

Dark-fine grained differentiate of granite.

Nearly vertical joints and cracks.

50 0 100

SCALE OF FEET

Geology by W.H. Irwin, Grant Gordon, and R.L. Nichols.

FIG. 7- Map of a portion of northeast abutment for **GRAND COULEE DAM** showing structural details of finished excavation.

tion in the Tertiary lava. Earthquakes are recorded at Spokane but the site is far removed from known active zones.

The three systems of joints[12] are classified according to prominence in the following order.

1. NNE.—vertical
2. NNW.—dipping steeply NE.
3. NNW.—5°–15° SW.

They have little effect on the character of the granite.

The principal fault zones (Fig. 6) influenced erosion and weathering of bedrock (Fig. 7). As a result excavation of these features was carried some distance below the level of the surrounding floor. Trenches produced in this manner were filled with concrete and grouted.

EXPLORATION

Preliminary investigations of the site were made by vertical diamond-drill holes. These disclosed a remarkably even rock floor with a few conspicuous depressions. The overburden did not exceed 150 feet. Later in the program other diamond-drill holes and numerous calyx (shot)-drill holes, 36 inches in diameter, were added. Compression tests in the laboratory on 24 core specimens gave an average ultimate strength for the granite of 15,500 pounds per square inch (minimum, 5,280; maximum, 29,700).

MARSHALL FORD DAM, TEXAS

A program regulating the flood menace on the Colorado River in Texas contains several units, the largest of which is Marshall Ford Dam.[13] This straight-gravity concrete structure (Fig. 1), reaching 270 feet above the lowest point in the foundation, was built during 1937–1942. The site is in the west-central part of Travis County, 12 miles northwest (upstream) of Austin, Texas. Besides the concrete part of the dam, wing dikes, earthen embankment, extend on each side to higher ground. The project has a dual purpose of flood control and power development.

GENERAL GEOLOGY

The rocks of Travis County,[14] sedimentary in origin, belong to the Comanche series of Cretaceous age. The section includes the Washita, Fredericksburg, and Trinity groups, with the latter resting unconformably on Paleozoic strata. Further division into various formations is made, separated again, in some instances, into subordinate members.

The canyon is cut in the Glen Rose formation (upper Trinity), which is at the

[12] W. H. Irwin, "Geology of the Rock Foundation of Grand Coulee Dam, Washington," *Bull. Geol. Soc. America*, Vol. 49 (1938), pp. 1627–50.

[13] K. B. Keener, "Marshall Ford Dam," *Engineering News-Record* (December 1, 1938), pp. 697–99.

[14] R. T. Hill and T. W. Vaughan, "Description of the Austin Quadrangle (Texas)," *U. S. Geol. Survey Folio 76* (1902).

surface over a considerable area adjoining the reservoir basin. The formation locally has a vertical range from an elevation 450 feet above river level to a depth, according to exploratory data, of approximately 205 feet below the channel. Drill holes penetrated 100 feet into the underlying Hensel "sands" of the Travis Peak formation.

The bedding is essentially horizontal for a long distance. The Balcones fault, the nearest major geological structure, extends in a north-northeasterly direction several miles from the dam along a line passing through Austin. In many places, its position is marked by an escarpment. So far as known, the region is seismically inactive.

LOCAL GEOLOGY

The Glen Rose formation consists of alternate hard and soft layers of limestone, sandy limestone, shell limestone, marl, and clay. Stratification at the dam site dips about 5 feet in 1,000 feet, making possible easy correlation of key members on both abutments. Physical inequalities manifested by selective erosion on the surface are not so apparent in drill cores. Shaly layers slacked upon exposure, necessitating cleaning of the foundation immediately before concrete was placed.

The sequence of soft or porous beds, referred to the left abutment (looking downstream) is given in Table I.

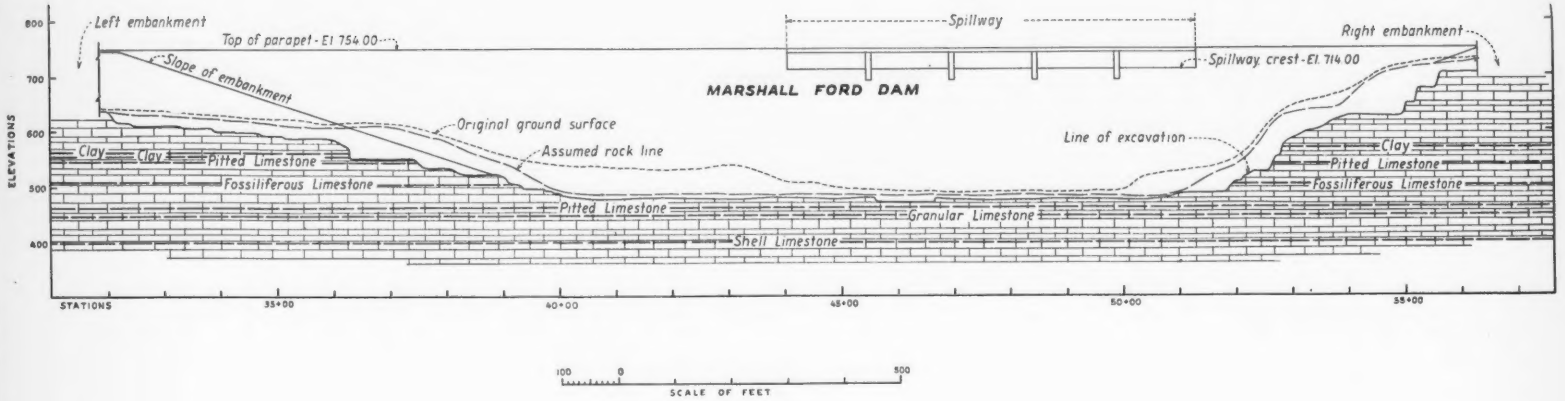
TABLE I

Item Number	*Thickness in Feet*	*Description*	*Elevation of Base in Feet**
a	12	Clay and shale with a few thin limestone members	639
b	1	Gray shale, compact unless weathered	619
c	1	Marly limestone; solid	611
d	1	Clay shale; compact if not weathered	605
e	2	Clay shale; compact where fresh	601
f	1	Gray clayey limestone; compact where unweathered	595
g	1	Marly shale, compact	585, 579
h	3	Weathered, yellow clay shale and leached shell strata. This is most porous abutment formation, showing total drill water loss when penetrated	565
i	3	Gray clay shale; solid unless weathered	555
j	$\frac{2}{3}$–$\frac{5}{6}$	Gray clayey limestone, compact before exposure	547
k	2	Porous, fossiliferous limestone; hard	543
l	$\frac{7}{12}$–$\frac{5}{6}$	Soft, black clay; soft	542
m	2	Gray shale; solid before exposure	524
n	2	Gray shale; compact until exposed	516
o	1	Porous, fossiliferous limestone; hard	510

* All members except b, c, and d, which are absent, appear at elevations 10 feet lower on the right abutment. All thicknesses are approximate.

FOUNDATION PROBLEMS

Regularity of bedding is a convenience in correlation but sedimentary formations can be physically more variable than foundations composed of igneous and metamorphic rocks. Each contact between layers is a potential weakness. The



EXPLANATION

Bedrock is the Glen Rose formation consisting predominantly of limestone with thin clay and shale parting beds.

—— *Porous or soft zones; cut off by tunnels backfilled with concrete above river level*

Geology by J. L. Darnell

FIG. 8 - Section looking downstream along axis, showing bedrock features of **MARSHALL FORD DAM**

dip is an important factor in reception of stresses, distribution of seepage, and success of grouting. Flat, relatively thin members tend to slide under the downstream thrust of the dam and to separate when excessive grout pressure is applied.

The occurrence of hard and soft layers in the Glen Rose formation, including porous and incompetent units, complicates the preparation of the foundation at Marshall Ford. Obviously, the stability of horizontal strata depends in part on the adequate support of each bed. The extent and position of critical features (Fig. 8) are indicated in Table II.

TABLE II

Location	*Elevation (Feet)*	*Thickness of Bed (Feet)*	*Seepage Loss*	*Material*
Left (east) abutment	565	1–3	20 gpm/gravity	Yellow clay—shell limestone
	555	3	Small	Gray clay
	543	1	Small	Leached fossiliferous limestone between clay layers
	510	1	10–15 gpm/gravity	Fossiliferous limestone
Valley floor	466	?	Erratic	
	463	4–6	Erratic	Pitted limestone
	452	Irregular	Erratic	Granular limestone
	400	9–16	Artesian (a) Discharges 6 gpm at elev. 490 (b) Takes 16 gpm/105#	Shell limestone
	249	Variable	Unknown	"Sands"
	416	Variable	Unknown	"Sands"
Right abutment	555	Variable	Leaky	Yellow clay
	537	Variable	Leaky	Pitted, black shaly limestone
	509	1	Leaky	Loss along bedding in limestone

In order to confine soft material which might be squeezed under load as well as to block seepage following openings, pairs of tunnels were excavated along the listed members on each abutment beneath opposite faces of the dam. These drifts were then back-filled with concrete and grouted. In the case of beds immediately underneath the foundation, controlled grouting was used to impregnate cracks and to fill cavities. Zones at a considerable depth have proportionately less significance.

Random vertical fractures over the rock floor in some places were healed with calcite or plugged by infiltered mud. If possible, these were carefully washed and grouted from special holes drilled to intersect them at different levels.

Aside from ground-water movement normally following porous layers above the stream, artesian flow was disclosed by exploration into the Hensel "sands" more than 200 feet under the river. The importance of the artesian flow is diminished by the consideration that accumulated head indicates both the comparative imperviousness of overlying beds and the remote origin of intake, perhaps beyond the reservoir basin.

SHASTA DAM, CALIFORNIA

CENTRAL VALLEY PROJECT

The great basin of the Sacramento (north) and San Joaquin rivers is confined between the Sierra Nevada (east) and the Coast Ranges in California. It contains a vast inhabitable area extending more than 400 miles north and south and has an average width of at least 40 miles.

The streams from opposite ends unite nearly midway to discharge into San Francisco Bay. The flow is greatly increased by run-off of many important tributaries, chiefly from the Sierra Nevada. The normal supply of water, supplemented by wells in the southern, San Joaquin section, is insufficient either for existing irrigation requirements or future development. Abundant water, causing periodical floods, on the other hand, is available in the northern, Sacramento River drainage. The Central Valley Project is a plan for ultimate equalization and utilization of this resource.

Shasta Dam, on the Sacramento River north of Redding, California, is under construction. It will serve as a key feature to realize a measure of flood control, salinity control in the bay area (resulting from tidal bore), to provide power, and allow better distribution of water by exchange and direct canal diversion. This is a gravity structure,[15] curved in plan except for the central spillway portion, reaching 602 feet above the lowest point excavated in the foundation. It will have more than 6 million cubic yards of concrete besides an earthen embankment on the southwest (left) abutment. Work was started in 1938, and under the accelerated program recently instituted, should be finished in 1944.

GENERAL GEOLOGY

Early investigations by Diller[16] outlined geological conditions in the region. Subsequent study by Hinds,[17] Graton,[18] and others has modified somewhat the original interpretation of certain features.

Formations, Cretaceous or older (Fig. 9), occur in considerable thickness despite nonconformities signifiying extended periods of erosion. Pre-Cambrian schists appear a few miles southwest of Redding so that the complete stratigraphic column presents some of the earliest rocks in the state. Sacramento Valley at its northern end has a synclinal form limited by the Cascade (east) and Coast Ranges. This structure is reflected in the areal distribution of various formations.

Absence of marine sediments younger than Cretaceous shows that the region has long been elevated. Tertiary and later formations are of stream or volcanic origin.

[15] "Review of Shasta Dam Plans," *Western Construction News* (April, 1938), pp. 175–82.

[16] J. S. Diller, "Description of the Redding Quadrangle, California," *U. S. Geol. Survey Folio 138* (1906).

[17] N. E. A. Hinds, "Paleozoic Eruptive Rocks of the Southern Klamath Mountains, California," *Univ. Calif. Dept. Geol. Sci. Bull.*, Vol. 20 (1932), pp. 375–410.

[18] L. C. Graton, "The Occurrence of Copper in Shasta County, California," *U. S. Geol. Survey Bull. 430* (1910).

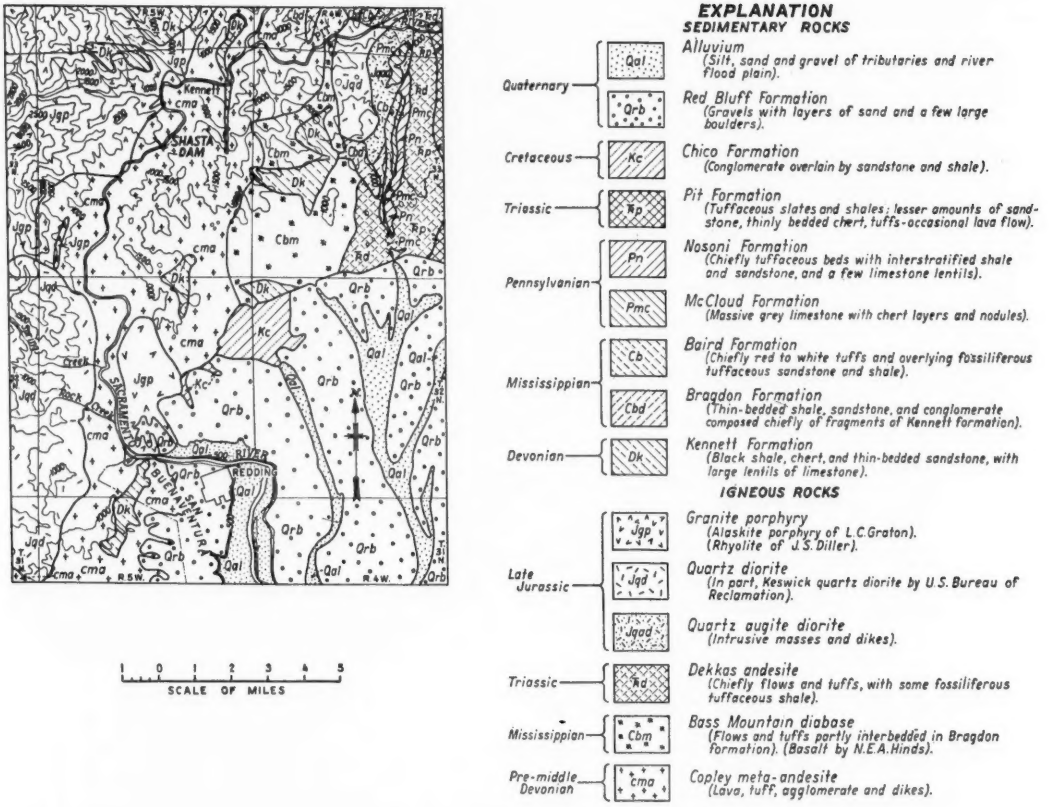


FIG. 9 - Location Map of SHASTA DAM with principal formations. (Modified after J.S. Diller, G.F.138, and N.E.A. Hinds, Vol. 33, Univ. of Calif. Geol. Pub.)

Large intrusions of diorite and granite porphyry cutting the pre-Cretaceous series are contained in prominent north-south belts (Fig. 9). These have been regarded of probable Jurassic age and the source of mineral deposits in the district.

Lava and tuffaceous material in part or entirely composing many formations characterize the region as a persistent volcanic province throughout most of recorded geological time.

The dam site is more than 50 miles from faults known to be active or potentially disturbing. The effects of earthquakes have been considered in design along with light shocks occasionally emitted by Mt. Lassen (on the east). The dam is believed to be relatively secure.

LOCAL GEOLOGY

Bedrock at the dam site[19] and for many miles in either direction along the Sacramento River is meta-andesite belonging to the Copley formation (pre-Devonian). The sequence of lava, tuff, agglomerate, conglomerate composed of reworked material, with numerous dikes of andesite, diorite, and dacite, no doubt is repeated several times. The total thickness is not known but is in excess of the greatest depth reached by exploratory drilling.

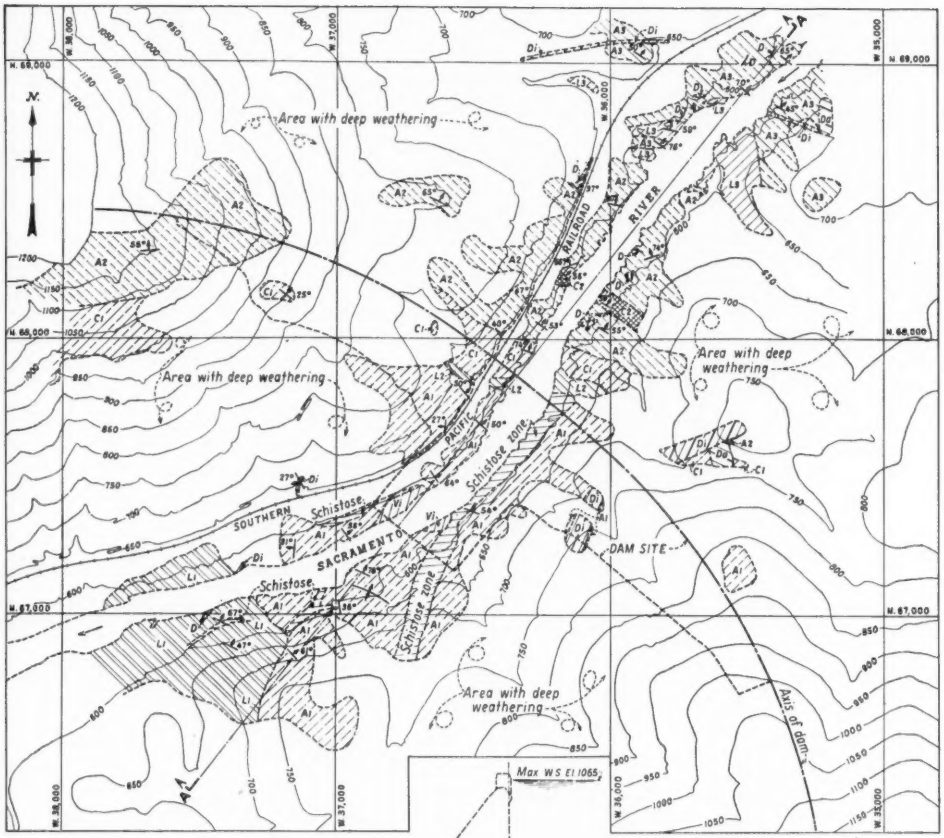
Metamorphism was due both to the weight of incumbent formations and effects of near-by large intrusions. The intensity diminishes with distance from these igneous bodies. For construction purposes the meta-andesite is a uniform rock. In detail, marked differences exist in physical condition of the undisturbed, massive portions of the formation compared with material in fault zones or schistose layers trending at a slight angle to the river.

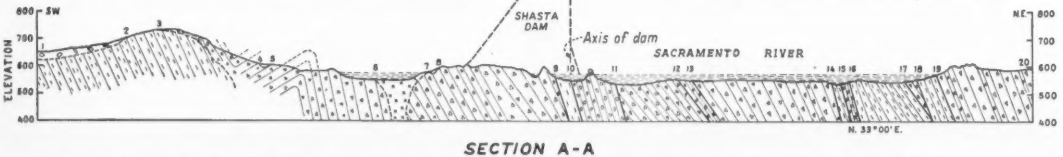
The agglomeratic facies composing most of the foundation area occurs between lava layers beyond the site (Fig. 10). Stratification, more or less indistinct on freshly excavated surfaces, is pronounced below flood level along the channel due to effects of selective erosion. The average dip is 50° upstream in a direction opposed to seepage from the reservoir. The strike, nearly at right angles to the river, west of the stream swerves gradually south. This is perhaps a result of crowding by the granite porphyry chonolith on that side, one-half mile from the canyon.

The meta-andesite originated from scattered vents in the district. A plug-like mass of elliptical outline along the river below the axis and numerous andesitic dikes in the section show a local source for some of the material. Less than 5 per cent of the larger fragments are granite obtained from distant points.

The large diorite and dacite dikes (Fig. 10) on the east (left) abutment roughly parallel the canyon in conformance with the principal structural pattern. These bodies are genetically related to the Jurassic intrusions elsewhere in the district (Fig. 9).

[19] G. D. Louderback and F. L. Ransome, "Geologic Report on Kennett (Shasta), Iron Canyon and Table Mountain Dam Sites on Sacramento River," *State of California Dept. Pub. Works Bull. 26* (1931).





SECTION A-A

1-2 Residual soil; 2-3 Lava; 3-4 Agglomerate with conglomeratic members; 4-5 Residual soil and river sand; 5-6 Agglomerate; 6-7 Volcanic plug; 7-8 River sand; 8-9 Mostly agglomerate but having conglomeratic lenses; 9-10 Lava; 10-11 Conglomerate; 11-12 Thinly bedded agglomerate; 12-13 Conglomerate; 13-14 Chiefly heavy beds of agglomerate; 14-15 Lava; 15-16 Interbedded agglomerate; 16-17 Lava; 17-18 Interbedded agglomerate; 18-19 Lava; 19-20 Agglomerate.

EXPLANATION

UNCONFORMITY

DEVONIAN (?) -- COPLEY meta-andesite*: a complex series of highly metamorphosed rocks of volcanic origin and andesitic composition including agglomerate, lava and conglomerate derived therefrom; the formation is believed to represent an essentially continuous process; of probable local origin from scattered sources in region.

A3 Agglomerate -- Bedded debris similar to other underlying horizons.

L3 Lava -- Youngest of flows mapped at damsite. The interfingering of lava and sediment reflects alternating eruption and explosion.

C2 Conglomerate -- Lens of conglomerate within agglomerate, A2.

A2 Agglomerate -- Basal portion is thinly bedded suggestive of stream action but the series becomes increasingly coarser towards top.

C1 Conglomerate -- Consists in main of rounded cobbles but also includes angular fragments indicative of concurrent volcanic disturbance.

L2 Lava -- Interbedded flow.

A1 Agglomerate -- Chiefly heavy beds of volcanic sediment forming the main body in the foundation of the dam. There are conglomeratic layers recognizable in the basal portion.

L1 Lava -- Oldest flows encountered at damsite.

INTRUSIVE ROCKS

D Dikes -- Consanguineous dikes in the Copley meta-andesite.

Vi Volcanic plug -- A stock of glassy rock possibly marking the source of some flows in the area.

Da Dacite porphyry -- Jurassic.

Di Quartz diorite -- Large and small dikes of diorite of Jurassic Age.

*J. S. Diller -- Redding Folio #138: U.S. Geological Survey: 1906.

100 0 500
SCALE OF FEET

FIG. 10 - Geological map and profile section showing sequence of bedrock members at SHASTA DAM.

FOUNDATION PROBLEMS

Weathering is advanced in the meta-andesite on account of susceptibility of the rock to alteration and due to the acid character of meteoric waters in contact with disseminated sulphides. The outline of rock suitable for a high dam not only was concealed by overburden but did not agree precisely with topographic expression. The magnitude of the problem is illustrated by the fact that more than 3 million cubic yards of material had to be removed in stripping operations ranging in depth from 50 feet, on an average, to more than 200 feet in one area.

The fault and schistose zones contain gouge and sheeted rock. These and certain contacts had to be specially treated to avoid differential settlement and excessive seepage. The method adopted is standard and flexible. Excavation in depth and form was continued along them to levels determined by a formula providing adequate percolation distance and bearing support. The trenches with deep shafts at opposite ends (Fig. 11) then were back-filled with concrete and grouted. Drainage and inspection tunnels, overlapping in vertical section, were driven at different elevations into both abutments. They intersect all questionable features, permitting observation and additional treatment, if necessary, after the reservoir is filled.

EXPLORATION

The dam site was explored on three occasions. The final investigation prior to construction consisted of 10,196 feet of diamond-drill holes, 188 feet of 36-inch calyx (shot)-drill holes, 183 feet of shafts, and 4,400 feet of tunnels with crosscuts. As excavation progressed, 6-inch calyx holes were drilled to disclose unsuspected conditions immediately beneath the foundation.

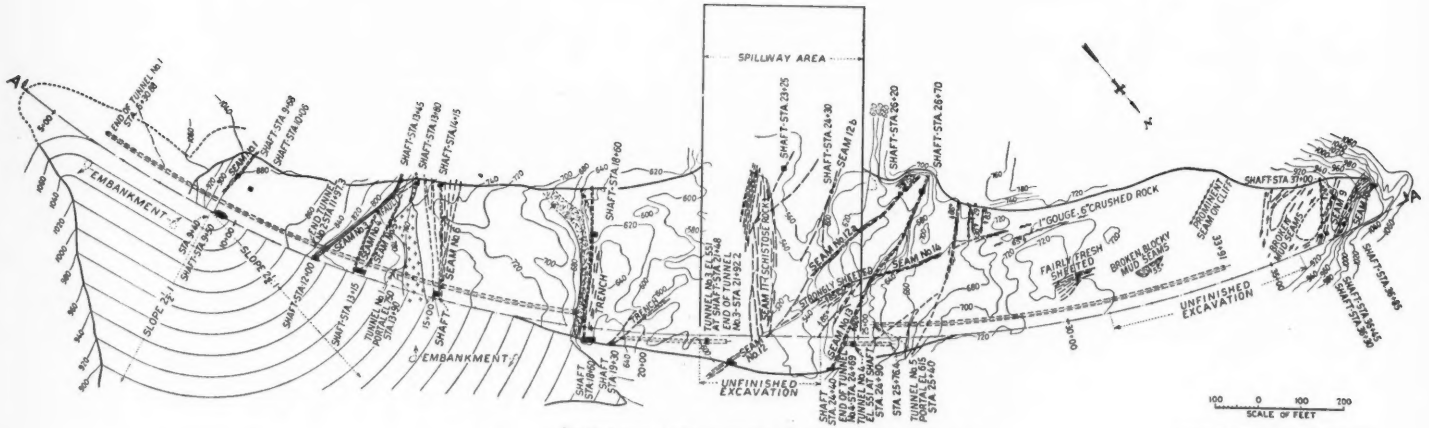
Compression tests in the laboratory on 54 core samples from points scattered over the area gave ultimate strengths for the meta-andesite averaging 12,050 pounds per square inch (minimum, 535; maximum, 35,400).

FRIANT DAM, CALIFORNIA

Friant Dam is located near the small town of Friant, 20 miles east of Fresno, California. The San Joaquin River at that point leaves the canyon cut in the western foothills of the Sierra Nevada. This stream with several tributaries is the principal source of water for irrigation of a vast area in the San Joaquin Valley.

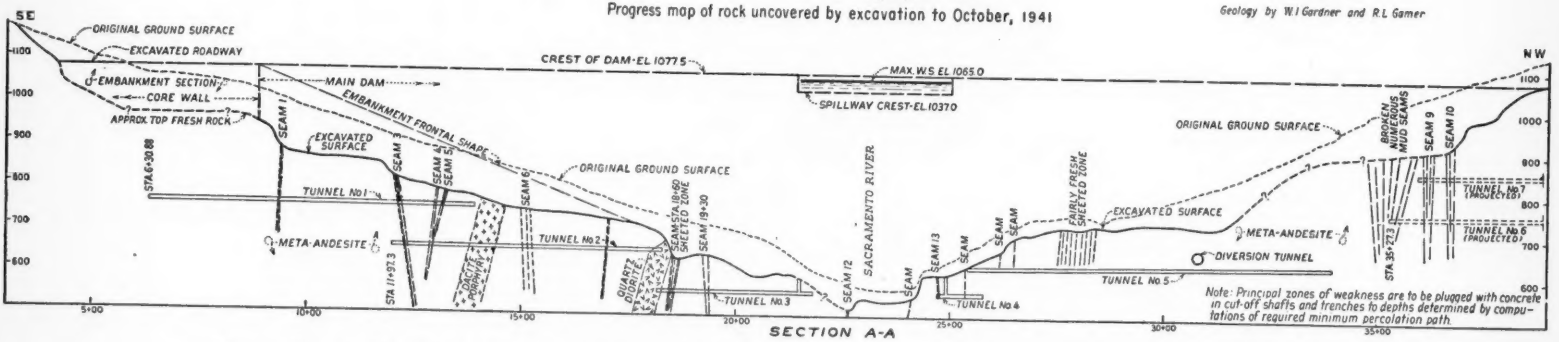
The dam is the key feature in a plan consisting of a storage reservoir regulating run-off and lengthy canals leading in opposite directions along the east side of the valley. The dam[20] contains nearly $2\frac{1}{4}$ million cubic yards of concrete and is a straight-gravity structure reaching 320 feet above the lowest point of bedrock in the foundation. Construction began in 1939 and is practically finished in early 1942.

[20] K. B. Keener, "Friant Dam Plans Provide Unusual Design Features," *Western Construction News* (August, 1939), pp. 270–72.



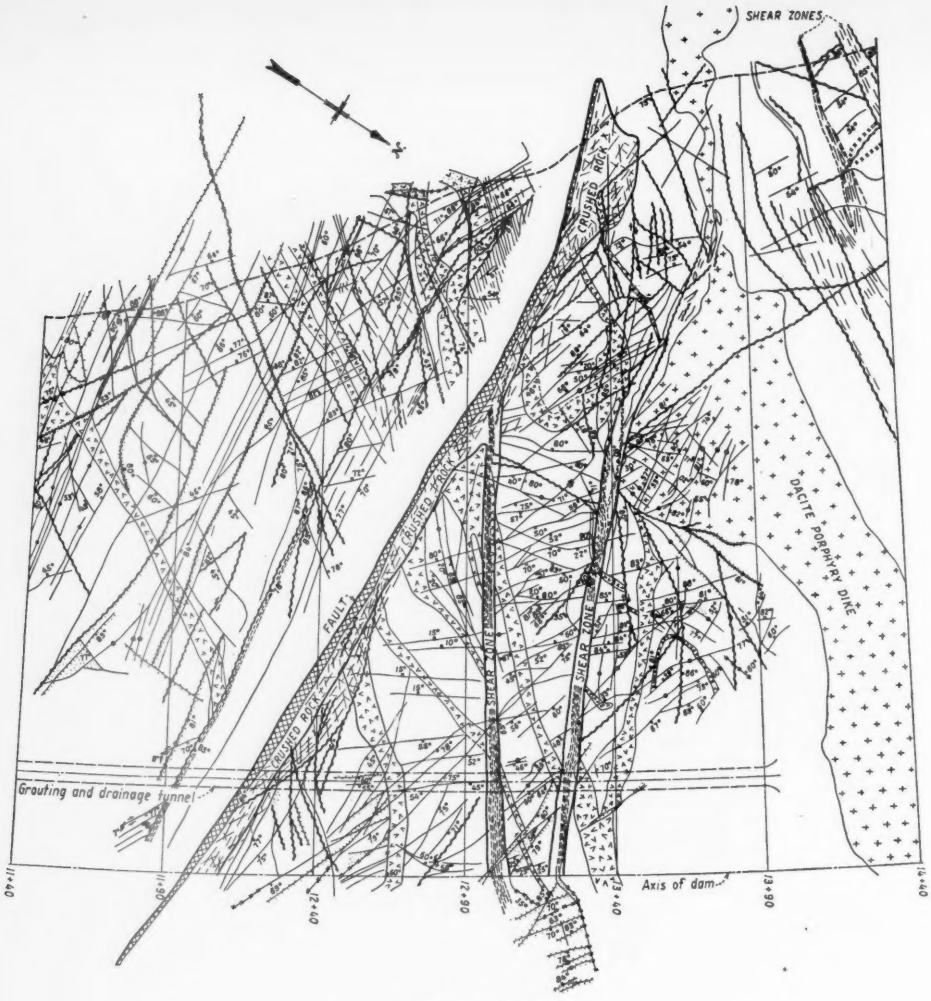
Progress map of rock uncovered by excavation to October, 1941

Geology by W.I Gardner and R.L Gamer



SECTION A-A

FIG. 11 Plan and profile section along axis showing principal geological formations and structures of partly excavated foundation for SHASTA DAM



EXPLANATION

Rock is meta-andesite, unless otherwise indicated.

- *Meta-andesite dike.*
- *Dacite porphyry dike.*
- *Fault containing gouge.*
- *Crushed zone.*
- *Shear zone with sheeted structure.*
- *Minor shear or slip seam.*
- *Closely spaced joints, sheeted structure.*
- *Joint.*
- *Soft, brown, strongly altered material along seam.*
- *Heavy stain or moderately altered material along seam.*

NOTE

Open areas have not been completely mapped.

Geology by R. Gamer and W. I. Gardner.

FIG. 12 - Map of a portion of southeast abutment, SHASTA DAM showing structural details of finished excavation.

GENERAL GEOLOGY

Jurassic granodiorite of the Sierra Nevada batholith locally entraps a roof pendant of quartz mica schist. The metamorphic rocks occupy a wide strip at right angles to the canyon, and in part are phyllites indicative of sedimentary origin.

The site is a considerable distance east of the San Andreas rift. So far as determinable, no faults showing signs of geologically recent activity occur within proximity of the dam. Possible effects of earthquakes are considered in design but it is believed that the chance of serious disturbance is slight.

LOCAL GEOLOGY

The lines of schistosity in bedrock of the foundation trend in general at a small angle to the axis of the dam[21] and dip steeply downstream. Intimate intermingling of schist and granitic material from the invading granodiorite is characteristic. The relation is also indicated by diorite dikes in general conforming to the direction of schistosity (Fig. 13).

Fairly fresh rock appears along the river below flood level. Weathering is progressively more intense on the valley slopes, ultimately forming an altered zone 40–50 feet thick at the crest of the dam.

Two important structural patterns were disclosed by investigation. The left (southeast) abutment is crossed obliquely by a strong fault with branch fractures containing varied amounts of gouge and sheeted rock. Some of these follow one or the other wall of diorite dikes, indicating renewed disturbance after intrusion. The fault system, comprising an area excavated in trapezoidal section, passes through the excavation between the lower part of the left abutment and the spillway section in the river below the dam. Because the dip is steeply downstream and into the valley side, the zone extends beneath rock suitable for foundation. As a consequence, each branch structure was excavated by trench to formula depths between deep shafts under opposite faces of the dam. These were then filled with concrete and grouted.

A subordinate system of small slips and seams, sloping gently northwest and striking roughly parallel with the river, dips into the right (northeast) side. These undercut otherwise sound rock on that abutment in a manner allowing possible settlement and rapid seepage. They were similarly treated where necessary by means of cut-off drifts in pairs, subsequently filled with concrete and grouted.

EXPLORATION

The project was investigated several years ago by 22 diamond-drill holes and a few test pits to determine the character of rock and amount of overburden. Before construction began the final axis was selected on results of added exploration. Tunnels totaling 1,100 feet with cross-cuts were driven into the base of

[21] Hyde Forbes, "Geological Reports on Dam Sites in the San Joaquin River Basin, California," *State Dept. Pub. Works Bull. 29* (1934), pp. 571–76.

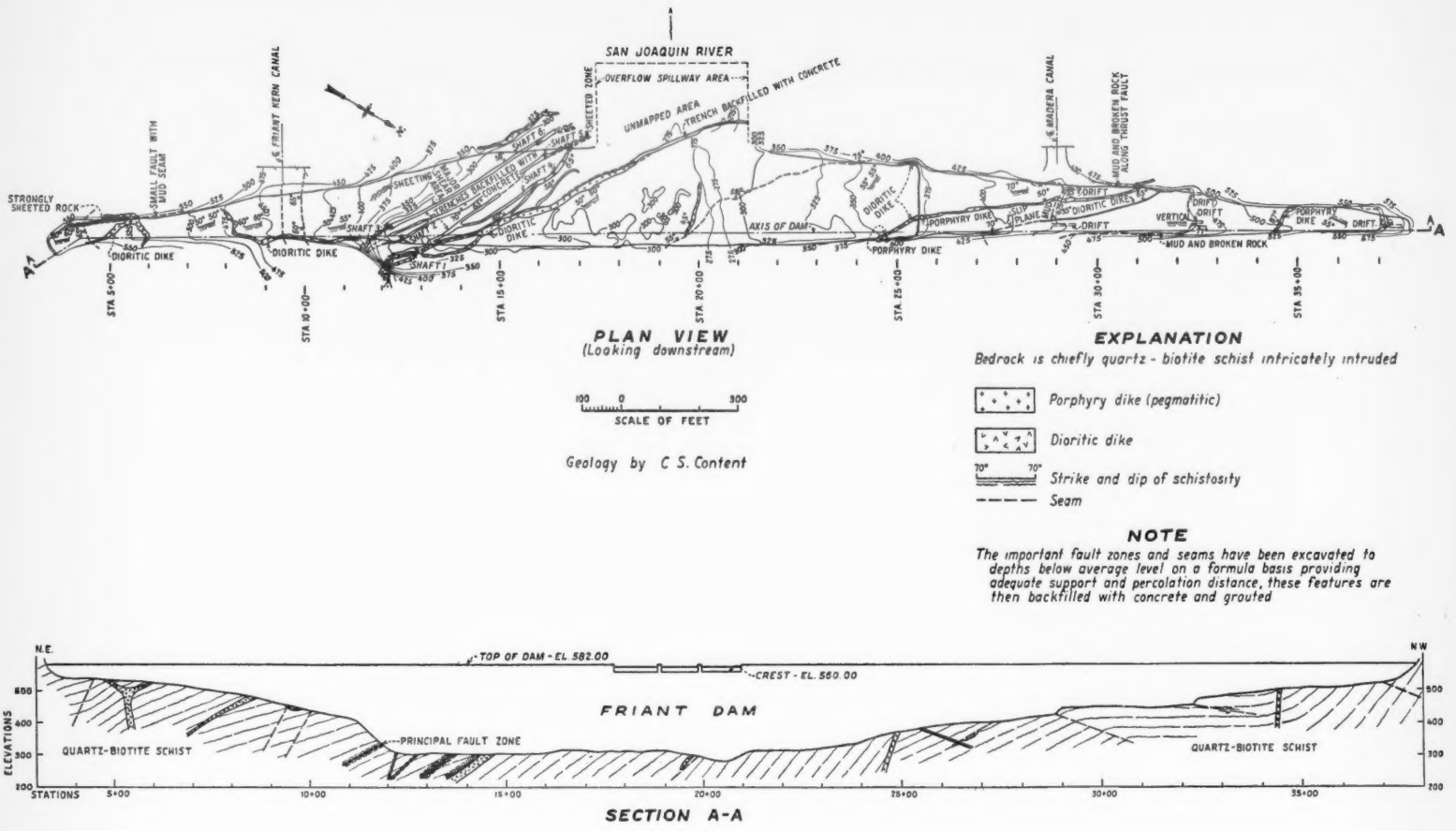
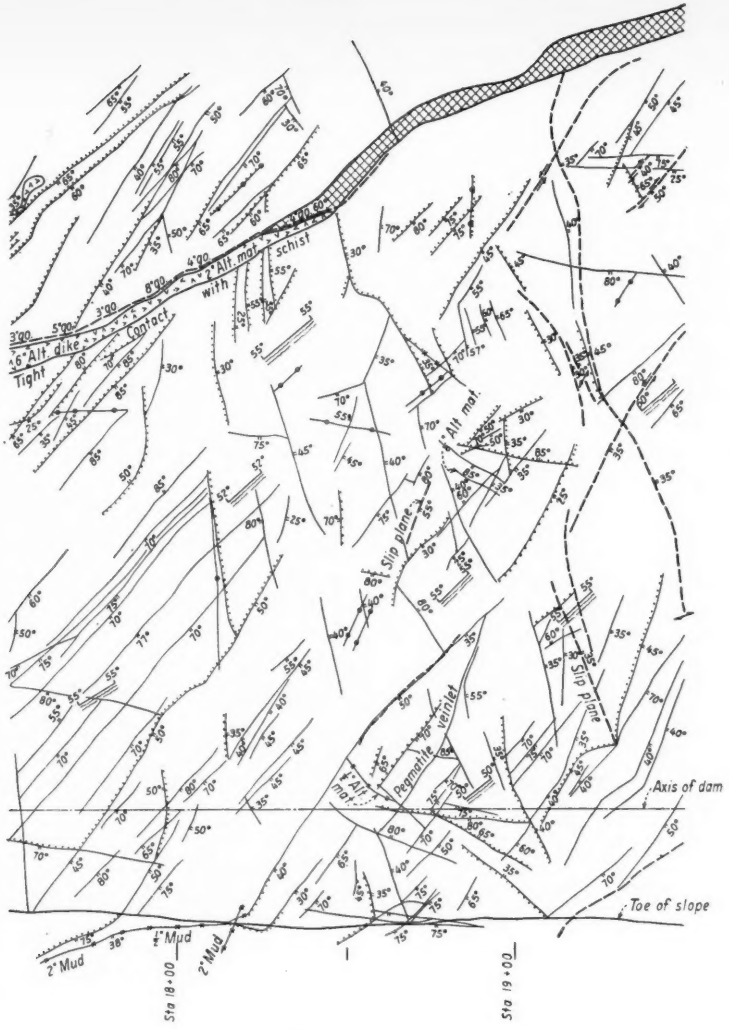


FIG. 13 - Plan and section showing principal structural features of excavated foundation for FRIANT DAM.



EXPLANATION

Bedrock is chiefly quartz-biotite schist, with diorite intrusions.

- *Dioritic dike.*
- *Seam backfilled with concrete.*
- *Joint with dip.*
- *Vertical joint.*
- *Stained joint.*
- *Mud seam or joint with altered material.*
- *Slip plane showing relative direction of movement.*
- *Strike and dip of schistosity.*

Geology by C. S. Content

10 0 50 100
SCALE OF FEET

FIG. 14- Detail of a portion of the spillway at FRIANT DAM showing structural features of excavated foundation.

each abutment; eight calyx (shot) holes, 36 inches in diameter and aggregating 392 feet, were drilled at points over the canyon floor, while diamond drilling, 3,557 feet, involved 30 vertical and angle holes. Later detailed drilling of the fault zone is not included. In the final stages of exploration 6-inch calyx holes were drilled to an average depth of 30 feet for inspection of rock immediately under the foundation.

Compression tests in the laboratory on 66 core samples from different parts of the area indicated an average ultimate strength for the schist of 9,630 pounds per square inch (minimum, 1,460; maximum, 20,680). Unweathered specimens broke along planes according to orientation of the strain ellipsoid, regardless of direction of schistosity.

CONCLUSIONS

The engineer has at his command long established methods of controlling manufacture and placing of materials used in construction. Conditions of nature remain the most uncertain factors influencing success and safety. Geology offers the only logical means of securing a reasonable understanding of foundation problems. Appreciation of this fact is demonstrated by the increased employment of geologists as a necessary part of major engineering organizations.

ACKNOWLEDGMENT

It is desired to acknowledge the source of information on details illustrated in the discussion. The work of staff geologists has been freely used, particularly studies by W. H. Irwin, Grant Gordon, and R. L. Nichols at Grand Coulee Dam, Washington; W. I. Gardner, R. Gamer, and C. S. Content at Shasta and Friant dams on the Central Valley Project, California; and data by J. L. Darnell, formerly at Marshall Ford Dam, Texas.

The Denver office of the Bureau of Reclamation is under the direction of S. O. Harper, chief engineer, W. R. Young, assistant chief engineer, and J. L. Savage, chief designing engineer. John C. Page is Commissioner of Reclamation, Washington, D. C.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 12 (DECEMBER, 1942), PP. 1827-1842, 4 FIGS.

GEOLOGICAL NOTES

CALCULATING THE TRUE THICKNESS OF A FOLDED BED

G. D. HOBSON[1]
London, England

In making use of borehole data, it is quite common to infer that the true thickness of a bed is its vertical thickness multiplied by the cosine of the angle of dip of the bed. Such an inference is strictly true only when the bed is plane, and it becomes less and less accurate the greater the dip and the greater the ratio of the true thickness of the bed to its radius of curvature.

The possibility of inaccuracies arising in the above manner does not appear to be considered generally, although it is usual to bear in mind, when calculating

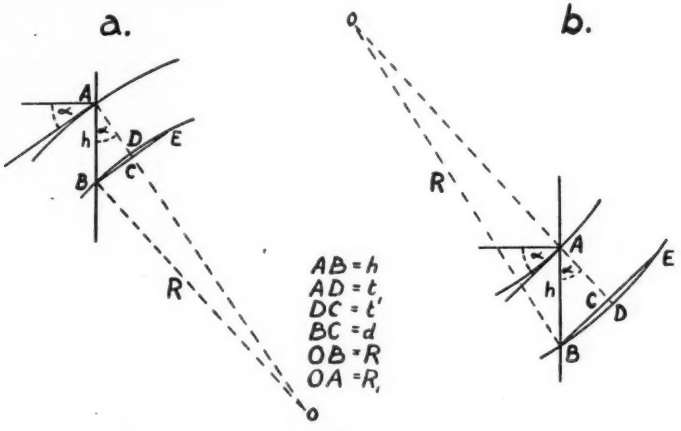


FIG. 1

thicknesses by means of the cosine formula, that the results may be in error due to wedging of the beds caused by depositional conditions or by the sharp folding of incompetent beds. Instances in which it is essential to apply the equations developed in the following paragraphs rather than the simple cosine formula are relatively rare, but it seems to be of some importance to ascertain the magnitude of the error which may arise from the use of the cosine formula for thickness calculations on curved beds.

Consider a borehole AB (Fig. 1, a) passing vertically through a competent bed of true thickness $AD=t$. The simple assumption gives the "true thickness"

[1] Professor of geology, Imperial College of Science and Technology, Prince Consort Road, South Kensington.

of the bed as $AB \cdot \cos \alpha = h \cdot \cos \alpha = AC = AD + DC = t + t'$, where t' is the error in the resultant value. Suppose that the curvature of the bed in the vicinity of the borehole makes the radius of curvature of the upper surface R_1, and that of the lower surface R. By a simple geometrical proposition it can be shown that:— $d^2 = t'(2R - t')$, $2d$ being the length of the chord BCE. Hence $t'^2 - 2Rt' + d^2 = O$, and therefore $t' = R \pm \sqrt{R^2 - d^2}$. Inspection shows that the negative sign must be used before the square root term.

But $d = h \cdot \sin \alpha$ and $R = R_1 - t$, and substituting for d and R in the above expression for t' gives

$$t' = R_1 - t - \sqrt{(R_1 - t)^2 - h^2 \cdot \sin^2 \alpha}.$$

However, $t = h \cdot \cos \alpha - t'$, and elimination of t from the previous equation with subsequent solving for t' leads to

$$t' = h \cdot \cos \alpha - R_1 + \sqrt{R_1^2 - 2R_1 h \cdot \cos \alpha + h^2}.$$

The percentage error is $\epsilon = 100 \cdot t'/t$, and since t is approximately equal to $h \cdot \cos \alpha$,

$$h \cdot \cos \alpha, \ \epsilon = 100 \left[1 - \frac{R_1}{h \cdot \cos \alpha} + \sqrt{\left(\frac{R_1}{h \cdot \cos \alpha} \right)^2 - \frac{2R_1}{h \cdot \cos \alpha} + \sec^2 \alpha} \right]$$

to a first approximation.

The error t' is given by the same relationship when the curvature of the bed is in the opposite direction (Fig. 1, b) from that considered above (Fig. 1, a) provided that $-h \cdot \cos \alpha$ is written for $h \cdot \cos \alpha$, but the thickness calculated from the simple cosine formula is too low in this case instead of being too high.

Figure 2 shows the effect of the angle of dip of the top of the bed on the percentage error, for $R_1/h = 5$ and for $R_1/h = 10$. It is clear that when the dip becomes steep and the ratio R_1/h small, the percentage error is no longer negligible.

The foregoing discussion assumes that a normal to the curve of the bottom of the bed is also a normal to the curve of the top of the bed, i.e., that the folding is parallel or competent. If this condition does not obtain, the argument is no longer valid, and when the beds behave incompetently or are competent but sharply wedging, the problem is not susceptible of any simple satisfactory solution in the absence of a considerable amount of data.

The method of determining the radius of curvature of the top of the bed in order to compute the true thickness, the error t', or the percentage error ϵ, will vary with the form of the available information.

If the top of the bed has been stratum contoured, a simple geometrical method can be applied to determine the radius of curvature. Suppose that A, B, and C are the positions of three successive contours on a dip section (Fig. 3, a) passing through the borehole, the borehole lying between A and C. On bisecting the lines

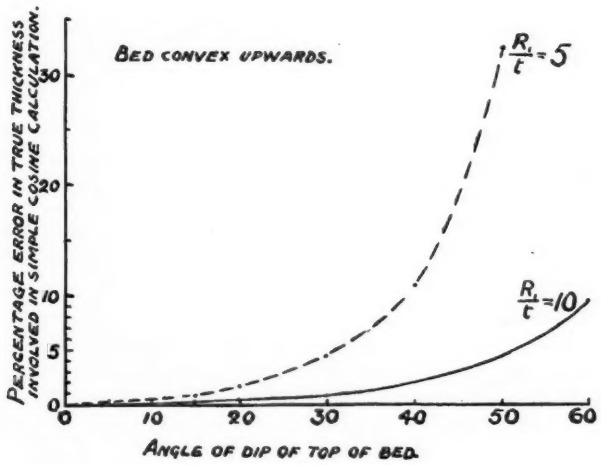


FIG. 2

AB and BC, and erecting perpendiculars at their mid-points, O, the point of intersection of the perpendiculars, will be the center of the circle passing through A, B, and C.

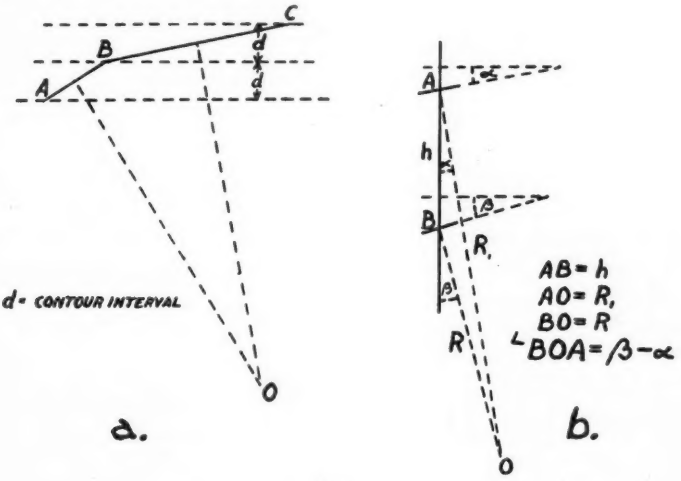


FIG. 3

When core dips for the top and bottom of the bed provide the only data from which to derive the radius of curvature, again a geometrical method can be adopted. The center of the concentric circles which pass through A and B (Fig.

3, b), and have tangents dipping at the dip angles shown by the two cores, is the point of intersection of the perpendiculars drawn to the dips at A and B. The trigonometrical solution in this instance is

$$R_1 = \frac{h \cdot \sin \beta}{\sin (\beta - \alpha)}, \quad \text{for} \quad \frac{h}{\sin (\beta - \alpha)} = \frac{R_1}{\sin (180° - \beta)} = \frac{R_1}{\sin \beta}.$$

It may be noted that if the local curvature is spherical, or at least circular in the dip direction, the direction of dip will be the same at the top and bottom of the bed. Any marked difference in the direction of the two dips is indicative of more complex curvature or of other conditions which invalidate the basic assumptions made here in calculating the curvature and thickness.

If the data consist of the dips at two points on the upper surface of the beds, the two points lying in a dip direction, the trigonometrical solution is as follows. Y is the horizontal separation of the two points where the dips are α and β, and d is their vertical separation (Fig. 4, a). $Y+Z=X \cdot \tan \beta$; $Z=R_1 \cdot \sin \alpha$;

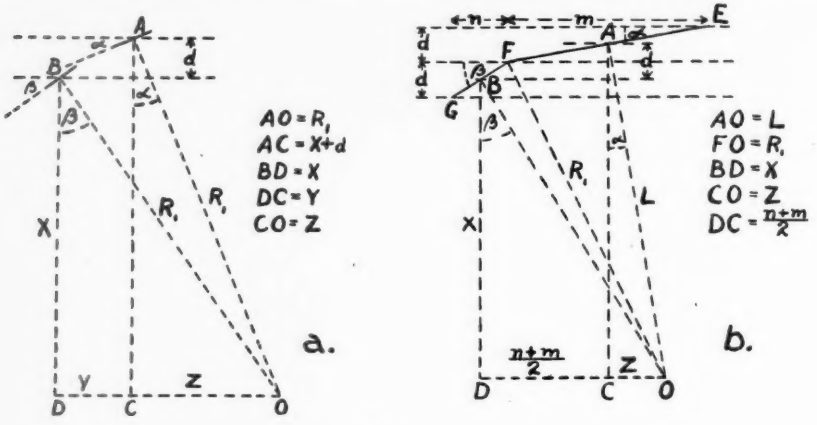


FIG. 4

$R_1^2=Z^2+(X+d)^2$. Substituting in the last equation values of X and Z derived from the first two equations gives

$$R_1^2 = R_1^2 \cdot \sin^2 \alpha + \left(\frac{Y + R_1 \cdot \sin \alpha}{\tan \beta}\right)^2 + 2d\left(\frac{Y + R_1 \cdot \sin \alpha}{\tan \beta}\right) + d^2.$$

This may be rewritten as

$$O = R_1^2\left[\sin^2 \alpha - 1 + \frac{\sin^2 \alpha}{\tan^2 \beta}\right] + R_1\left[\frac{2Y \cdot \sin \alpha}{\tan^2 \beta} + \frac{2d \cdot \sin \alpha}{\tan \beta}\right] + \frac{Y^2}{\tan^2 \beta} + \frac{2dY}{\tan \beta} + d^2$$

$$= R_1^2\left[\left(\frac{\sin \alpha}{\tan \beta}\right)^2 - \cos^2 \alpha\right] + R_1\left(\frac{Y}{\tan \beta} + d\right)^2 \frac{\sin \alpha}{\tan \beta} + \left(\frac{Y}{\tan \beta} + d\right)^2.$$

Solving for R_1,

$$R_1 = \frac{-\frac{\sin\alpha}{\tan\beta}\left(\frac{Y}{\tan\beta}+d\right) \pm \sqrt{\frac{\sin^2\alpha}{\tan^2\beta}\left(\frac{Y}{\tan\beta}+d\right)^2 - \left(\frac{Y}{\tan\beta}+d\right)^2\left[\left(\frac{\sin\alpha}{\tan\beta}\right)^2 - \cos^2\alpha\right]}}{\left(\frac{\sin\alpha}{\tan\beta}\right)^2 - \cos^2\alpha}$$

$$= \frac{\frac{Y}{\tan\beta}+d}{\cos\alpha - \frac{\sin\alpha}{\tan\beta}}.$$

In the trigonometrical solution for the radius of curvature when stratum contours are given for the top of the bed, let AO and BO (Fig. 4, b) be the perpendiculars drawn at the mid-points of the lines EF and FG, E, F, and G being the contours in the dip section; and let the horizontal separation of E and F be m, and of F and G, n. If d is the contour interval, the vertical separation of A and B will be d. Then

$$\frac{Z + \frac{m+n}{2}}{X} = \tan\beta, \quad \frac{Z}{X+d} = \tan\alpha \text{ and } L^2 = Z^2 + (X+d)^2.$$

Also

$$R_1^2 = L^2 + (FA)^2 = L^2 + \left(\frac{m}{2\cos\alpha}\right)^2.$$

Substituting for L in the last relationship and then eliminating X and Z gives

$$R_1^2 = \left(\frac{\frac{m+n}{2} + d\cdot\tan\beta}{\tan\beta - \tan\alpha}\right)^2 \cdot \tan^2\alpha + \left(\frac{\frac{m+n}{2} + d\cdot\tan\beta}{\tan\beta - \tan\alpha}\right)^2 + \left(\frac{m}{2\cos\alpha}\right)^2$$

$$= \left(\frac{\frac{m+n}{2} + d\cdot\tan\beta}{\tan\beta - \tan\alpha}\right)^2 \cdot \sec^2\alpha + \sec^2\alpha\left(\frac{m}{2}\right)^2.$$

$$\therefore \quad R_1 = \sec\alpha\sqrt{\left(\frac{\frac{m+n}{2} + d\cdot\tan\beta}{\tan\beta - \tan\alpha}\right)^2 + \frac{m^2}{4}}, \text{ where } \tan\alpha = \frac{d}{m},$$

$$\tan\beta = \frac{d}{n}, \quad \text{and} \quad \sec\alpha = \frac{\sqrt{m^2+d^2}}{m}.$$

In calculating the error in the thickness of the bed as deduced from the simple cosine formula, lack of more data may make it necessary to use a core dip for the dip of the top of the bed, i.e., a value which may be purely local, but it is

probably more satisfactory generally to use a dip determined from the spacing of the stratum contours on the top of the bed if available.

GEOLOGY AND WAR[1]

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Geology has played its part in all wars from those in which the crude stone hammer was the principal weapon down to the present war wherein all sciences contributing to mastery of air, land, or sea, are being utilized to their fullest degree.

It is unfortunate that persons who have had no training in or contact with the field of geology do not properly appreciate its greatest usefulness. Geologists themselves, especially the American and British—but not German and Japanese—have been slow to organize an educational geologic program to augment the military and naval services of the country, and the latter have been slow in making immediate adequate use of the important knowledge which the science of geology and the country's trained geologists can supply.

This neglect on the part of geologists has been matched by a general ignorance of or indifference to geology by military and naval officials; and by the tendency of other types of technicians—geophysicists, engineers, geographers, meteorologists, etc.—to assume that geology is a minor adjunct of their own field.

The strategic worth of economic and topographic geology may be evaluated by its general application to the following activities which are of vital importance in wartime.

A. Interpretation of terrain for military purposes.
B. Conversion of terrain for military use.
C. Maintenance of supplies and communications.
D. Miscellaneous geologic applications.
E. Expansion of normal domestic geologic activities.

A. *Interpretation of Terrain for Military Maneuvers.*

Although modern warfare is exceedingly complex, it is basically a series of maneuvers for and upon portions of the earth's crust—land, sea, and air. In so far as it involves activity upon the land, it is occupying an arena that has been and is now the subject of intensified study by the geologist and common sense recommends that an expert on that arena be consulted.

Several examples will be listed wherein even without special military training, the competent geologist can contribute opinions of weight and matters of fact.

[1] Manuscript received, November 2, 1942. Reprinted by permission from the *Journal* of the Association of American State Geologists.

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1. *Analyses of terrain for troop movement, attack and defense.*

The field geologist has intimate knowledge of the processes that produce earth features. Better than any other technician, he can analyze a terrain, appreciate its topography and understand its contours. This ability is a function of his particular training and with it a geologist is equipped to make complete and rapid analyses of the ground. He can do this from observation, from maps, from photographs, or from another's description.

2. *Interpretation of unknown topography from geologic literature, photographs, and published geologic maps.*

Constantly the geologist is required to make detailed interpretations of conditions of topography and geology in regions that he has never seen. Such requirement is part of his academic training and later becomes an integral item of his personal experience. There is probably no other technician who has an equal ability to visualize these conditions from maps and documents. Given access to published literature, a corps of trained field geologists could operate from a Washington office to give better geologic and geographic advice about the character of unknown terrain than an observant native of the region under study.

Furthermore, there is probably no major portion of the earth's surface that has not been examined on the ground by some living geologist now resident in this country; and for most areas of the globe an American geologist can be found who knows the country intimately, its contours, climate, resources, and even its language.

3. *Appraisal of mineral producing regions or objectives, their types, values, accessibility, and military importance.*

This is the specific field of the trained geologist who is fully accustomed to the survey, appraisal, and interpretation of natural mineral resources. It is likely that there are no important mineral deposits in the world which some resident American geologist has not visited, or about which first-hand information as to type, value and reserves, is not readily available.

To mention a few specific examples: There are probably a score of petroleum geologists who are wholly conversant from recent experience with the oil fields of Borneo, Sumatra or Java. American geologists and engineers are personally familiar with all important mineral operations of Central and South America.

4. *Fluid appraisal of foreign or enemy mineral resources.*

It is important to have a fluid appraisal of the changing character of foreign or enemy mineral resources, and as already indicated the geologist is in a position to keep abreast of these changes.

5. *Fluid interpretations of relative vulnerability in terms of topography, mineral and water supply and general accessibility.*

In matters of both tactics and strategy the fluid appraisal of these matters must currently be given careful study.

Probably no previous war has so fully vindicated the need of constant interpretation of changing conditions in the light of new developments. The fortifications of Singapore, Hong Kong, the Maginot and Mannerheim lines are the product of 1918 strategy. Their strategic importance could well have been different if the last two decades of military science had placed more emphasis on the geologic aspects of the land.

6. *Interpretation analysis of current geologic problems encountered during military campaigns.*

Here again the geologist should be consulted to furnish current, fluid interpretations of situations that may be progressively changing.

7. *Selection of testing areas to simulate terrains of possible campaigns.*

Since the war is world wide, no portion of the earth's surface may escape free from it and every actual type of terrain is involved—the glaciated areas of high mountains and high latitudes, the jungle as well as the desert areas, the hinterland and the coast line. Indeed, the latter is a subject of specialization in itself. Coast lines are quite variable and are different where the sea is transgressing from where it is regressing. The geologist is able to advise as to testing grounds that will duplicate conditions of anticipated campaigns, and can there give counsel in the testing and use of men and equipment destined to enter combat in specific environmental conditions.

8. *Actual reconnaissance.*

The geologist should be employed in reconnaissance in advance of occupation of territory; he should be prepared to make current geologic surveys of it during occupation; and should carefully study any territory to be relinquished, in all three instances being able to provide information of military value.

9. *Analysis of shore features to determine coastal conditions of beach, off-shore depth, and landing or siege conditions.*
10. *Interpretation of climate, soil, vegetation and terrain in terms of living conditions, sustinence and occupation.*
11. *Appraisal of sites for roads, encampments, mines, batteries, airdromes, and other semi-permanent installations.*
12. *Solution of many problems dealing with the conversion of ground for military use as discussed below.*

Most of these functions need little or no specific explanation at this point; they are simple obvious points where the applications of geologic principles and practice are patently of considerable importance.

B. *Conversion of Ground for Military Use.*

In the conversion or adaptation of ground for military use, geology becomes a prerequisite to engineering, and skilled geologic advice is a vital necessity in

virtually every phase of this work. Many of the items listed below will be claimed by the engineer as his field; yet he will have to call upon his own geologic training, often inadequate and at best woefully meager, to solve the problems raised. Civilian activities of most geologists with the pursuit of their profession provides the background to step into service in many of the following categories, and there should be no difficulty in finding geologists now who can serve the armed forces along these lines with little or no military training necessary.

It would be possible to considerably enlarge each of the particular geologic problems connected with the following topics, and any trained geologist is competent to do so. It should also be noted that nearly all of the following listed items have both a positive and a negative aspect—namely, a side dealing with construction, use, and offensive purpose, and a side dealing with demolition, prevention, and defensive purpose. Geology is of assistance on both sides.

1. *Construction of trenches, fortifications, artificial impediments, munition dumps, earthworks, and similar installations.*
2. *Construction of airdromes, runways, shelters, foundations, etc.*
3. *Blasting, tunnelling, mining, and quarrying.*
4. *Construction or prevention of rock or earth slides, fills, slopes, rock cuts, and similar excavations.*
5. *Reclamation of swamps, marshes, quicksands, etc.*
6. *Flooding, drainage, construction of dams, levees, canals, reservoirs, wells, etc.*

In all of these activities, the civilian geologist is commonly consulted, and his advice is basically responsible for the engineering success of many of these projects. Seemingly his advice should be as eagerly made use of in analogous military operations on the success of which a far greater outcome may rest than any civilian operation.

The geologist should be employed to assist in making the original location; to give advice concerning the topographic advantages of the site chosen; to advise regarding the character of earth handled, the depth of overburden, methods of excavation required, available construction materials, drainage properties of rock and soil, strength of foundations, type of surfacing needed, reaction of explosives; and he should be consulted in the protective or defensive demolition of previously constructed installations.

7. *Stability, strength, character, and workability of any given ground of material.*

In determining these important factors the geologist can give quicker and more reliable aid than any other technician.

8. *Reclamation of shelled territory, rock fragmentation through bombardment, etc.*
9. *Utilization of caves and caverns; operation and exploration of mines and other underground workings.*
10. *Conversion of local mineral industries for military use.*

It should not be necessary to amplify the above topics in order to reveal the importance that geology has at each point.

C. *Maintenance of Supplies and Communications.*

In civilian life, the entire field of mineral detection, prospecting, discovery, and appraisal, falls in the area of geologic science, as well as many allied problems of mineral recovery and development. Specially trained geologists are now available to do similar necessary service in military life. For example:

1. *Prospecting and reconnaissance for supplies* of road metal, brick clay, raw stone, marl ballast, sand, material for concrete, and other native materials of potential military use.

One whole side of military activity must deal with the maintenance of supplies indicated above, for which the geologist is better prepared to search and exploit than other technicians.

2. *Drilling, excavations, and quarrying* for the immediate use of the above materials.

3. *Hydrologic problems, ground water, springs, etc.*

Another broad field for the geologist is that of ground and surface water, the location of wells, determinations of source of springs, water supply, filtration of water and permeability of rock and soil, depth of water tables, source of ground water, underground water storage, etc.

4. *Location and construction of roads.*

In the location of construction of military roads or other lines of transportation, the supervision of location, selection of ballast, types of road construction, etc., the geologist can render as adequate military service as he has long been doing in similar civilian activities.

D. *Miscellaneous Geologic Applications.*

There are numerous other categories in which the geologist, because of his general training or because of certain specific specialization or experience, can perform valuable functions not usually considered. These points may be briefly listed without special elaboration.

1. *The magnetic detection of mines*, pipes, metallic underground installations and other geophysical service.

2. *The construction and detection of camouflage* should be definitely in the geological field, for the geologist is better acquainted with the appearance of the ground than anyone else.

3. Matters of sanitation and burial are closely allied to the geologic problems of underground drainage.

4. Gas retention in rock and soil.

5. Restoration of captured or damaged installations such as oil wells, mines, etc.

6. General map making and surveying.

7. Scouting and general reconnaissance. It should be noted here that the field geologist is an experienced hand in getting about under adverse conditions, with a minimum of equipment, and under conditions where resourcefulness is a necessary asset.

E. *Expansion of Normal Domestic Geologic Activities.*

Finally, the manifold activities of geologists in general civilian affairs need to be specially geared to the war effort. Some of these duties take on new applications no less important than the active military applications listed above. These things, as well, should be given careful thought.

1. Continued and more intensive search for strategic or essential mineral deposits.

2. Evaluation of known low-grade or normally non-commercial supplies of critical raw materials. (Example, manganese, zinc, iron ore, etc.)

3. Experimentation with substitution of unused resources of value as replacements for materials now exhausted. (Example, high alumina clays.)

4. Geologic advice on engineering problems of domestic defense, new military and industrial installations, roads, dams, wells, foundations, airdromes, camps, etc.

5. Assembling of maps, geologic literature, and appraisal of geologic opinion concerning other possible applications of geology to the needs of the armed forces.

6. Instruction at service schools and preparation of textbooks on military geology.

7. Preparation of military guide books and maps.

8. Reorganization of geologic courses taught in colleges and universities so as to further the dissemination of knowledge of matters of geologic importance.

9. Reorganization of existing geologic societies and agencies into the most effective coöperation with military and naval authorities.

10. Continued reiteration of the practical value of geology in both war and peace.

Recommendations

1. An organization should be set up within both the Army and Navy to create and direct a geologic corps for advice, consultation, and technical geologic application. These organizations should be fitted into the present military and naval structures so as to distribute trained geologists wherever there is opportunity to make use of their services, particularly as listed in the following paragraphs.

2. A selected group of mature trained geologists should be assigned positions in the military organizations, with sufficient military or naval ranking that their technical advice carries adequate authority.

3. These key men should have the responsibility and authority to set up or direct the procurement of other trained geologists to be fitted into the military or naval organizations on such a basis that their services can be most useful.

4. There should be a small group of trained geologists assigned to the preparation of a geologic handbook for military use.

5. An organization should be contemplated, if not now set up, so as to make the most practical use of this science both in the post-war settlement, and in possible future military or naval undertakings.

THE RHYMING LETTERS FOR VICTORY[1]

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"V" is for Victory. But this letter can not stand, balanced insecurely on wishful thinking. It must be buttressed, held strongly and unwaveringly upright. Search the alphabet for the letters that rhyme with "V" and you will find the needed supports. "C" is for Chemistry. "E" is for engineering. "G" is for Geology and Geography. "P" is for physics.

The scientists of the warring nations are pitted against each other. Engines unconceived a decade ago, powered by new fuels, propel monsters of the sky through a thin atmosphere that would bring death to the crew did not other products of science provide synthetic air for breathing and protection against the dry cold of the upper levels. These great ships are attacked by fighting planes that can surpass them in speed and in climbing ability, streamlined to reduce friction, and armed with ordnance of new design and deadly effectiveness. Submarines that can shake off the shock of a depth charge as a spaniel shakes off water are combatted by new methods of detection and of destruction. Tanks gallop where once they crept and their multiple tons of steel crush obstacles that, in the last war, were insurmountable, but they are countered and destroyed by mobile guns and penetrating projectiles and explosives newer in their conception than the machines they fight.

Less spectacular but equally vital are the activities that provide raw materials, that insure the adequate and effective training of troops, that permit and speed the transport of men and materials, that indicate the localities most vulnerable to attack and easiest to hold and permit us to strike and to defend with the utmost intelligence and knowledge. In these activities geology and geography have shared. They can contribute even more abundantly.

Geology must shoulder much of the responsibility for the discovery of mineral resources, so that our industries may be strained as little as possible by shortages. Preference may be granted to the so-called "strategic" minerals but our obligation extends equally to the more prosaic. Refractory clays for furnaces, limestone not merely usable but best in quality and at the most accessible point, sand for glass, gravel and other aggregate for concrete, road metal that will not fail under more severe pounding by heavy traffic than a peace-time road will ever know. We will

[1] Reprinted by permission from the *Journal* of the Association of American State Geologists.

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need more and yet more petroleum and natural gas to make the fuel, the lubricants, the rubber and the explosives, and to fire the furnaces for all-out production.

It will be well for geologists to review the list of materials that may contribute to our industrial effort which is our war effort, and to consider the activities either in progress or contemplated. Neither delay nor unproductive expense should be traceable to the failure of a geologist to know and to disclose where needed materials may best be secured.

Since any construction or activity that involves rock or soil or running water or ground water also involves geology, it is the obligation of the geologist to interest himself in all such activities that may contribute to the effectiveness of the war effort, to anticipate difficulties and to facilitate action so far as his capacity will permit.

Military considerations may demand that the best be made of unfavorable conditions, so that the location of much construction and the selection of sites for cantonments and for airfields may leave much to be desired from the geologic standpoint. This is doubly possible when decisions are made under the pressure of emergency, with scant opportunity to weigh existing knowledge and no time at all to secure additional facts. The lack of military training and ignorance of some or most of the considerations that influence the military men in their decisions impose a severe handicap on the geologists. Obviously maximum benefits will be possible only when geologists become a part of the military machine and plans and considerations are disclosed to them so that they may consider all pertinent factors in making their recommendations. However, since at present there is no geological unit in the army, the civilian geologist must do the best he can by bringing to the attention of the highest possible authority any geologic consideration that may prevent mistakes and speed accomplishment.

We can not know how these suggestions will be received or what consideration will be given to them, nor is this our immediate concern. We can not wait to be asked for our opinions for this involves the fallacious assumption that all those responsible for decisions recognize that geologic factors should be considered. It is our duty to our country and to our science to make our knowledge available, not for the asking, but insistently. It might have made a difference at Pearl Harbor had there been those who could and would have clamored about the approaching Japanese planes. It might have made a difference at Singapore had there been those who could and would have advised that certain of the swamps and rice paddies that were thought to be impassable obstacles for men and machines were, in fact, no such obstacles. It might have made a difference in Burma had there been those who could and would have indicated the areas where heavy mechanized equipment was worse than valueless and those where it could be used.

For example, since it is clear that our fighters can be trained fastest and best if cantonments are most effectively located with respect to terrain, soil conditions in wet and in dry weather, and with assured ease of access by rail and by road,

the civilian geologist should be quick to inform the army of shortcomings of any sites that he may learn are under consideration and to suggest alternatives which may seem to him more favorable.

Sickness or loss of efficiency due either to the quantity or the quality of water supply in cantonment or airfield in this country should never be traceable to the failure of geologists to recognize undesirable conditions and bring them to the attention of the army authorities.

In every region there are limited areas that are best suited for the construction and maintenance of all-weather airfields. It is the responsibility of the geologist to know and to point out these areas.

Military roads should be so located and so constructed that there will be the least possible interruption from the malevolence of nature. Selection of route to take fullest advantage of geologic conditions and knowledge concerning the possible extremes of heat and cold, of flood and snow, and of changes in ground-water level are primary requisites. If this information is not available when emergency dictates that a military road should be constructed with all possible haste, it should be assembled as quickly as possible so that the makeshift can be converted into a dependable traffic route as expeditiously as possible.

Very complete knowledge of rock and ground-water conditions is required if heavy foundations are not to fail. This is doubly true of construction that must bear the shock of artillery fire, as in coastal defense batteries, or must survive the continued vibration of heavy machinery. In most instances truly adequate information can be secured only from borings, but there have been unfortunate and costly mistakes that could have been avoided had geological evidence obtainable from a study of surface exposures been assembled and considered.

On the home front the civilian geologist may make his voice heard, just as have the physicists and chemists in their work on our weapons for attack and defense, but in our war efforts abroad it is imperative that the geologists be a part of the military machine. The first requisite is competent geologists with both scientific and administrative skill in staff positions. It is axiomatic that the most complete and effective application of a science can be realized only under the direction of executives skilled in that science. The field of knowledge is so broad that it is only the exceptional man who is really expert in more than a fraction of the science in his chosen field, and only a geologist can apprehend what geological information is obtainable and how it may be applied to simplify and speed our efforts.

These staff geologists must insure, so far as possible, that the geologic personnel assigned to different activities is adequate in quantity and quality and that it fully understands the needs and objectives. The staff officers must also organize and prepare for military use the geological information now available. They should also be responsible for the organization, training, and direction of units that will prepare and present, in the form of military maps, all pertinent information concerning topography, soil conditions, water resources, construction materials, and mineral fuels in any area that may be under consideration.

There should be both staff and field geologists with our forces in every separate area, the number and distribution of the geologists depending on the size and character of the area and the type of military operations that may be contemplated. It would be difficult to compile a full list of the contributions that may be expected from these resourceful men, but certain of their duties are easily apparent.

They must recognize and indicate the areas or localities where firm footing for tanks, troops, and transports is assured, and those where, either perennially or periodically, the rock, soil, or water conditions will create either an obstacle or a barrier. They must anticipate the changes both advantageous and harmful, that the change of seasons may bring even to the most favorable terrain and must be quick to recognize how military advantage may be taken of departures from expected seasonal conditions. For example, an abnormally dry season might result in an equally abnormal lowering of the ground-water table. This, in turn, might either be put to advantage by moving troops and equipment through terrain ordinarily soft and boggy or, conversely, it might be disadvantageous because of disappearance of a water supply that normally would be adequate.

They must secure and present in the form most useful to the armed forces the information that will permit advantage to be taken of weaknesses imposed by nature on positions held by the enemy and that will warn of such weaknesses in our own positions. Conversely, they must recognize strong situations that result from the nature and attitude and distribution of the rocks and the characters of the soil and of the waters that flow on the surface or that permeate the soil and the subsoil.

Upon them will fall the responsibility for developing information that will insure complete utilization of existing water supplies, will permit the development of additional and improved supplies, and that will warn against areas where an adequate local supply is either improbable or impossible. If it is essential to establish and maintain positions where a local supply is not obtainable they must locate the most advantageous suitable source and advise how a supply can, with certainty and dispatch, be provided to the "dry" position.

They must determine how existing roads can be shortened or otherwise improved by taking advantage of geologic conditions, and must indicate where additional roads can best be constructed to meet any needs that may arise.

They must recognize and indicate the most advantageous locations with adequate supplies of good water for airfields, base hospitals, and supply dumps. If deep drilling is essential they must know the approximate depth at which water will be found and be able to advise concerning the type of equipment needed to drill and complete the wells.

They must secure the knowledge that will permit the construction of dry, underground shelters for men and storage for supplies with maximum speed, greatest promise of security and simplicity of camouflage.

They must determine the location, availability and amount of construction material such as sand, gravel, rock suitable for road metal and for the manu-

facture of cement and quicklime. In few regions is there valid excuse for long-distance transportation of such materials.

They must be able to find and to aid in the development of such mineral resources as coal, petroleum, and natural gas if these minerals exist in an occupied area.

In a war of position they must meet the multitude of problems imposed by the occurrence of water in the ground and the characteristics of the soil and the subsoil on the effective construction of defense works and the destruction of those held by the enemy.

In the United States the Federal and the State Geological Surveys have a far greater opportunity to bring geologic considerations forcibly to the attention of the military than do the geologists who are engaged in educational or industrial activities. To these Federal and State organizations belongs most of the credit for such use of geology as has been made by our military forces during the early stages of the war effort. Conversely, where geology should have been used but was ignored, on these organizations must fall much of the blame.

The Federal Survey has a right and a duty to interest itself in any situation where the use of geology in this country or by this country may be important to the Nation. This right may not be written into its charter but its duty is no less clear than is the duty of the Public Health Service to combat disease wherever it may be found. The State Surveys have this same duty and this same right within the states to which they pertain.

The existence of the Federal and State Surveys does not lift responsibility from the geologist who is not affiliated with those organizations. His voice may be small and his opinion lightly considered, but he is derelict if he has knowledge that he believes will aid in the war effort and fails to do his utmost to impart that knowledge to those who could put it to good use. He is also derelict if he believes that a greater use of geology by our armed forces would advance the day of victory and yet fails to do everything in his power to bring about this use of his science.

Willingness is not enough. Initiative is needed. In a burning building a man who knew where the exits could be found would not place a placard on his chest announcing his knowledge and proudly wait for inquiries from an hysterical crowd. If we are right in our belief that intensive use of geology would be greatly in the National interest then upon us, the geologists, the only ones who, through experience and training, know and appreciate the many applications of our science, falls the obligation to persuade, convince and demonstrate until the "G" for Geology is one of the strong and dependable buttresses of the "V" for Victory.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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RESEARCH NOTES

ANNUAL REVIEW OF PETROLEUM GEOLOGY

A. I. LEVORSEN[1]
Tulsa, Oklahoma

An annual review of the progress in petroleum geology is being sponsored by the research committee of the Association. It is to consist of a statement of the significant new ideas, new principles, new philosophies and new methods which are described in the geological and technical literature of the world and which find application to petroleum geology. It is intended particularly to give our membership a quick and authoritative annual review of what is new in petroleum geological thinking with some idea of the significance of the articles reviewed.

Since the review is to cover the geological and technical literature of the entire world, it must be presented by someone, or some organization such as a University geological department, who not only has access to the literature but also reads it. I am glad to announce that the faculty of the Colorado School of Mines through F. M. Van Tuyl, chairman of the department of geology, has accepted our invitation to present the reviews for the next three years. It is planned that the review require not over 30 minutes to present orally at the annual meeting, and that it be printed in the *Bulletin* along with the annual reviews of development articles.

Anyone having knowledge of obscure yet significant articles which should be considered, or anyone with suggestions as to how the review might be made more valuable to the membership of the Association, is invited to communicate with Professor Van Tuyl.

[1] *Chairman*, Research Committee. 221 Woodward Boulevard.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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DISCUSSION

GEOLOGY IN WAR AND PEACE[1]

W. V. HOWARD
Tulsa, Oklahoma

Dr. Croneis has done geology a great service by pointing out that it occupies a most unenviable position among the sciences in the minds of everyone but geologists and some of their employers. His plea for more and better publicity, for the popularization of the science and for the establishment of suitable awards deserves very favorable consideration. I am, however, more interested in his suggestion that the blame for geology's present low estate can be laid at the door of the geologists themselves. That the low estate is a fact and not the personal jaundiced view of a single individual can hardly be disputed. Anything that Dr. Croneis has said on this score can be greatly amplified.

However, to say simply that geologists themselves are to blame does not get us very far. It seems to the present writer that Dr. Croneis has erred in not localizing much of the discredit a little more. It may be that as a college professor he is so close to the principal cause that he does not see it. For the blame for geology's present status and, particularly, for the fact that it does not attract the highest grade of student, can be placed almost entirely on the professors of geology.

Dr. Croneis has inveighed against the lack of union among geologists. What is more responsible for that lack of union than the splitting up of geology in college courses into a number of subjects which are neatly pigeon-holed and labelled and remain uncontaminated by contact with other branches? Everyone who has had any contact with colleges, outside of a few in the southwest and even including many in that area, knows the low opinion the professoriate has of petroleum geology.

When petroleum geology was developing, most of the pigeon-holes were already in existence. There was structural geology, there was sedimentary petrography, there was sedimentation, there was stratigraphy. Then along came oil. A few colleges proceeded to build another pigeon-hole for the upstart and courses in the geology of petroleum were offered, very grudgingly, however. Petroleum geology consists mainly of a study of the geology of oil fields, generally those in which the professional petroleum geologist has ceased to have any interest.

Outside of a sort of glorified Sears Roebuck catalogue of oil fields, there is nothing to petroleum geology, as everyone knows outside of the membership of the A.A.P.G. One simply finds an anticline and drills it. A course in petroleum geology can not include the material used every day by a district geologist in the field because that would be encroaching on other fields, robbing other pigeon-holes, which are jealously guarded by their custodians. If structural geology were included in the oil course, students taking it would not take the structure course and if registration fell off, the professor of structural geology might be out of a job.

Books on petroleum geology normally cover the course as taught in colleges. Because of the limited sale, there has not been a college text on the subject for over 10 years. The one most widely used starts off with the age-old discussion of the organic and inorganic origin of oil and rapidly slides into the Sears Roebuck phase. Its value as a practical text can be indicated best by its discussion of the East Texas field. That accumulation is covered by the following words, "Large deposits are developed also in Rusk County."

In their over-emphasis on the subdivision of geology into "fields," the colleges look at

[1] Carey Croneis, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 7 (July, 1942), pp. 1221–49.

the "field" labelled "petroleum geology" and consider that the petroleum geologist is a rather low class of animal life. If he fitted into the collegiate pigeon-hole prepared for him, he would be. That the petroleum geologist can best be classified as a man who applies all phases of geology to the discovery, exploitation, and development of oil fields is beyond the normal academic comprehension. There are no such men, except field geologists and, therefore, the oil geologist is simply a field geologist who looks for anticlines. There are also paleontologists, petrographers, sedimentationists, mineralogists, *et cetera*. There are, in addition, economic geologists who work on the geology of ore deposits. The only reason why this group is considered eminently respectable instead of occupying a lowly position alongside the oil geologists is that ore deposits were known before geology was ever thought of and the men who worked in the mines were among the founders of geology.

The pigeon-holing of fields also affects students in geology. The teacher of paleontology builds his science on sound principles of biology. The paleontologist is a technician who works with materials which he can study in detail in the laboratory. He can be said to be a scientist in the true sense of the word in that his conclusions are the result of observation and experiment and can be verified by every competent observer. That is, so long as he sticks to paleontology. However, when he steps into stratigraphy he gets into dangerous ground. He has less evidence to go on because 99 per cent of the evidence that he might need is buried or lost. He can only see outcrops. So he tends to crawl into his field and stay there. He has a rather low opinion of the petrographer, who can also study his materials and perform experiments, although to a much more limited degree.

The petrographer, mineralogist, and economic geologist (ore deposits only, please) overlap to a great extent. Their branch of the science is built on chemical foundations rather than on biological ones. There is a great cleavage between them and the paleontologists with the result that every course in mineralogy, petrography, or economic geology is taught as if there were no such subject as paleontology. Any courses in paleontology that I ever heard of bear the same relation to the mineralogy group.

Structural geology tends to deal with the Appalachians and Alps rather than with the Central Kansas uplift. That is just a piffling structure with no dips of over 15 degrees, so can not qualify. In the index of Willis' *Geologic Structures* we find 21 references to the Alps, 30 to the Appalachians, two to the Balcones-Mexia Fault zone, none to the Central Kansas uplift, the Nemaha granite ridge, the Cincinnati arch, salt domes, Arbuckles or Wichitas. The Ouachita uplift is mentioned once because it is a fine example of a synclinorium. This is not a criticism, it is merely a statement of what constitutes the material occupying the pigeon-hole labelled "structural geology."

To the student, therefore, geology is a series of jobs, not a unified one. There is a "structural geologist," an "economic geologist," a "paleontologist," *et cetera*, and the only connection between these professions comes in those colleges where a single professor teaches in more than one field, the connection between them being indicated by a repetition of the same jokes in class. The student is exposed to enough other sciences to know that they are taught as units and there is no specialization until after a solid foundation has been built.

One course in geology might demonstrate the unity of the subject, namely a course in the geology of the United States. How many such courses are taught? What is a good book on the subject? I may be mistaken but I think that the latest was written by Blackwelder in 1912. *Forest Physiography*, by Bowman, and *Oil Fields in the United States*, by Ver Wiebe, are more recent texts which may be considered substitutes, although their scope is necessarily limited. The reason why there are few courses taught on the geology of the United States and no books written is that there are no geologists, but only petrographers and paleontologists on our college faculties.

At this point, I can imagine the professors girding up their loins and preparing to wage

battle. "What about general geology," they may be imagined as saying, "the first course taught in every department of geology in the land?" Unfortunately the best reply to this question is that the first course in geology as taught everywhere is the main reason why geology is so unattractive to the higher grade student. Enrollment in that course is probably at least 10 times as great as in any other course in geology. Let us examine it in some detail.

In many colleges it is taught as a laboratory science. The reason for this is not inherent in the subject but is merely that a laboratory course is necessary if certain college requirements are to be met and if registration is to be reasonably large. Large registrations mean larger faculties and enough half-time assistantships to permit a number of graduate students to stay in school. In the face of these weighty considerations, the fact that Geology 1 laboratory is largely a farce is of no importance.

Of course, being a laboratory course, the student is expected to do some laboratory work. One exercise in the course which I tried, unsuccessfully, to teach required the beginning student to distinguish the minerals in sand, shale and loess. The number of students, professors, and others who can do this following not more than 8 minutes' examination under a microscope is exactly zero. The exercise was not rendered any more valuable by the fact that this was the first occasion on which most of the students had seen a microscope.

Frequently the course starts off with the study of 25 common minerals. If it doesn't start here they come in eventually. It really doesn't matter because after the student learns the specimens provided—specimens, not minerals—he uses a few of them in the study of rocks which follows and then promptly forgets them because they are not referred to again

The definition of a mineral which the elementary student learns is very interesting. One good definition taken from a text of the highest quality is that a mineral "is a naturally occurring substance that has a definite chemical composition and a definite combination of physical properties." That might include chicken livers but we'll let that pass. What it says is more interesting than what it omits. One of the minerals discussed is hornblende. According to Dana, hornblende "contains alumina or ferric iron and usually both, with ferrous iron (sometimes manganese), magnesium, calcium, and alkalies. Hydroxyl and fluorine are commonly present in small amounts; also titanium in many varieties." I may be quibbling, but that is not my idea of a definite chemical composition.

I must admit that the textbook from which I got the definition of a mineral does not mention "hornblende" as one of the common minerals. It refers to "amphibole" which is a mineral group crystallizing in three different systems and having a wide variety of hardnesses, and optical and other physical properties. Even the cleavage, which is the distinguishing feature, varies. However, in the elementary course this doesn't matter because the specimens are so poor that the cleavage doesn't show and the student learns that anything black and long that looks sort of fibrous is hornblende and takes the professor's word for the cleavage.

I could go on in the same way about other common minerals, such as plagioclase, garnet, chlorite and so on. There is, of course, another common mineral, native copper. This is so common that not 2 per cent of all geologists have ever seen it in the field. But the specimens available are really very nice.

After being filled with all of the misinformation about minerals that he can digest in a short time, the student goes on to the common rocks. In many laboratories there are no diorites so gabbros are substituted. Then diabase is called gabbro. Peridotite is a very common rock so that many laboratories introduce the element of surprise by using hornblendite or pyroxenite instead. We may now put away the trays because the student knows rocks and proceed with physical geology.

Here we learn all about such things as exfoliation, which experts in desert geology do

not seem to think very important, obsequent and consequent streams, the uniform distribution of gravel, and sand, and clay in nice parallel belts around the shore, the distinction between kames and drumlins, mesas and buttes, and about laccoliths, which are so easy to draw and so hard to prove in the field. We fill the student with a host of definitions and some very dubious geological principles so that, as one former colleague put it, we can devote the next 6 years to eliminating the false impressions gained in at least one field. When we achieve this noteworthy result, we signalize our success by awarding him the mystic letters "Ph.D.," which will act as a detriment throughout the rest of his career unless he goes into teaching or a government survey.

At least a part of the laboratory course will be devoted to the study of pictures and maps. The student soon learns that if he sees a long narrow ridge on a Maine map it is an esker, if in Colorado it is a dike. If the names are removed from the sheets, not even the professors can tell what it is.

At one staff meeting I asked the answer to a question the students were supposed to tackle. They were provided with a picture of a hill and asked "What name is applied to this type of hill?" There were six other professors in the room and I got the following answers, with confirmatory evidence, "butte, mesa, monadnock, kame, moraine, and drumlin." The last was advanced by the professor who had taken the picture and who explained that the evidence was plainly visible on the side of the hill which did not show in the photograph. My reply was that for two years I had been giving my class the answer which I thought was correct and I saw no reason to change my opinion. From the evidence contained in the picture, the only name which could be applied to that kind of hill was "hill." This was considered a feeble attempt to be facetious.

Other questions were designed to test the knowledge and reasoning powers of the students. My favorite was "On what side of Lake Michigan are sand dunes found? Why are they not found on the west side?"

After a semester of this sort of thing the good student who does not know from experience gained outside the classroom that all of the rest of his courses will not be the same as this takes bacteriology, sanitary engineering or, more probably, chemistry.

I admit that it is impossible to teach the elementary student the facts about mineralogy, physiography, tectonics, and other phases of geology, but why go to the trouble to teach him things which aren't so, interlarded with all of the rich jargon with which we cover our ignorance of the fundamentals of the subject? Why not start off with the world as we see it and leave its dissection to later courses? Admittedly geology is a circular subject. There is no beginning at which to start. If we discuss processes we presuppose some knowledge of earth materials. If we discuss materials we are compelled to pass off the processes which formed them with a statement that they are complicated and we are still forced to theorize about most of them.

The first course in geology should present a picture, not a lot of more or less unrelated and undigested definitions, some theories presented as facts and many misconceptions which even the professors recognize as such. If it is impossible to start the student with a bird's-eye view of the world in which he lives and we must be technical, I should recommend deferring Geology 1 to a later time and starting with historical geology. That course in any college which I have ever seen is interesting and it is generally taught by men who know something about it. It also refers very rarely to anything taken up in the general course.

Some of the advanced courses have very little practical value. Much of sedimentary petrography, for example, consists of looking for a few fragments of minerals which can be identified as coming from igneous rocks. Three pieces of zircon, some hornblende, garnet, and titanite in a cupful of sand may provide material for a paper.

However, my own personal favorite is structural geology. I once taught a course in that

subject as a substitute for a colleague on sabbatical leave. As so frequently was the case, the course as taught by me was not a complete success. Added to my own limitations, there was the fact that out of a class of seven, only one had had trigonometry and none had studied even high school physics.

I found particular difficulty in explaining the strain ellipsoid and drag folds. Of course, I knew that the strain ellipsoid dealt with a circle drawn in chalk on a piece of window-screen but it was never very clear what else it might mean until I went on a field trip along with graduate students and faculty members from the leading universities of three states.

On this trip we saw numerous outcrops of Cambrian and Ordovician formations. As all of the sandstones looked very much alike and the outcrops were separated by several miles, the stratigraphic part of the trip meant little. Later, after I had fallen from grace and became interested in oil, I learned that an oil geologist could have done much more with half a dozen trays of cuttings in half an hour than our guides did in a day and a half. However, I realize that the examination of cuttings is beneath the dignity of most professors of geology.

But the *pièces de resistance* of this trip did not deal with stratigraphy. At the end of a long day about 150 of us stood before a famous shrine of geology, the rock where the principle of the strain ellipsoid had been worked out. As our guide pointed to sundry cracks and cleavage planes the whole theory became suddenly clear and I was filled with admiration at this foundation stone of structural geology. Then the guide said that although the theory had been worked out here, the rock was not a good illustration because other evidence to be found elsewhere showed that the theory of the strain ellipsoid could not be applied in this particular area.

The next hallowed spot was the outcrop which had led to the development of the theory of drag folds. Again the bits of evidence were pointed out and again they combined to show the direction of the movement in this area. Unfortunately, however, the same thing was true of drag folds as had developed with the strain ellipsoid. The forces had actually operated in the opposite direction. However, it's a nice theory and is still taught in courses in structural geology to students who probably have had no physics and no trigonometry.

If Dr. Croneis' plea for more popularization and more publicity is to receive the attention which it deserves, I suggest that the program be not put into effect through the colleges.

It must be stated in conclusion that Dr. Croneis has rendered the profession of the teaching of geology a greater service by his article than anyone not on a college faculty could have done. He gives us reason to hope that the colleges may some day emerge from the late Pliocene. However, at the present time it is my firm conviction that any oil geologist can take a high-school graduate and with the aid of a single text, Lahee's *Field Geology*, and the routine operations of a field office make a better geologist out of him in 2 years than the colleges now do in four.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and available, for loan, to members and associates.

AERIAL PHOTOGRAPHS, BY A. J. EARDLEY

REVIEW BY W. A. VER WIEBE[1]
Wichita, Kansas

Aerial Photographs: Their Use and Interpretation, by A. J. Eardley. 200 pp. plus table of contents, list of plates, and index. Harper and Brothers *Geoscience* Series, New York (1942). Price, $2.75, postpaid.

The author of this book on the interpretation of aerial photographs is one of the pioneers in the University teaching of the preparation and examination of aerial photographs. Indeed, this book is in effect the eighth edition of Dr. Eardley's highly successful *Interpretation of Geologic Maps and Aerial Photos*, which he has used in lithoprint form in the classroom for a number of years. Thus the fundamental impression a reviewer gets is that the book is intended as a practical guide for class and laboratory work. The exercises are planned in such a manner that they refer to aerial photographs which are available in spite of war-time restrictions.

The first chapter is devoted to a brief summary of the uses and limitations of aerial photographs, as well as a more complete description of the cameras used in making the photographs. In the second chapter the principles which underlie stereoscopic vision and examination are fully treated. The contouring of vertical photographs is also described in the same chapter. The more difficult problems introduced by tilt, and the preparation of mosaics, are ably handled without the use of complicated mathematical fomulae. In fact the reviewer gets the impression that Dr. Eardley has tried to make the necessary concepts and processes clear throughout the book by graphic methods and simplified explanations rather than by recourse to academic mathematical proof.

The interpretation of features which come under the heading of "culture" is treated adequately in Chapter IV. In the next three chapters the author describes geologic maps and tells the reader how various kinds of geological phenomena may be detected on aerial photographs. The patterns made by outcrops of formations, unconformities, faults, igneous rock bodies, shore lines, are explained in great detail and with the aid of very carefully selected photographs. Helpful hints regarding the tone, texture, banding, vegetation, drainage patterns, insofar as they aid in the discrimination of geologic features, are summarized in Chapter VI. In Chapter VII the author describes the methods used in tracing geologic contacts and in preparing structure-contour maps and cross sections. Chapter VIII is devoted to the triangulation-net method and the perspective-grid method of using oblique aerial photographs for reconnaissance mapping. Finally, in the last chapter, the author tells briefly how military objects may be detected by a study of aerial photographs. Inasmuch as trained geologists are naturally adapted to the study and interpretation of aerial maps, they will welcome this book because it shows them how they may put their specialized knowledge to practical use.

[1] University of Wichita. Manuscript received, November 4, 1942.

RECENT PUBLICATIONS

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 16, No. 6 (November, 1942).

"Fusulinidae from the Phosphoria Formation of Montana," by Hugh Frenzel and Maurice Mundorff.

"Invertebrate Faunas from the Blaine and the Dog Creek Formations of the Permian Leonard Series," by R. L. Clifton.

"Permian Fusulinids from British Columbia, Washington and Oregon," by M. L. Thompson and Harry E. Wheeler.

"Ostracodes from the Upper Permian of Texas," by Irving B. Hamilton.

"Permian Nautiloids from Western United States, by A. K. Miller and A. G. Unklesbay.

"Missourian *Triticites* of the Northern Mid-Continent," by Benjamin H. Burma.

"Bibliographic Index of New Genera and Families of Paleozoic Ostracoda Since 1934," by Allen F. Agnew.

"Occurrence and Stratigraphic Distribution of Paleozoic Ostracodes," by Chalmer L. Cooper.

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BENJAMIN F. HAKE	ROBERT H. DOTT	GENTRY KIDD
ROBERT M. KLEINPELL	WAYNE V. JONES	HUGH D. MISER
NORMAN D. NEWELL	W. ARMSTRONG PRICE	RAYMOND C. MOORE
CHARLES W. TOMLINSON	HORACE D. THOMAS	
	WARREN B. WEEKS	

SUB-COMMITTEE ON CARBONIFEROUS

M. G. CHENEY (1945), *chairman*, Coleman, Texas

1943	1944	1945
BENJAMIN F. HAKE	ROBERT H. DOTT	RAYMOND C. MOORE
NORMAN D. NEWELL	HORACE D. THOMAS	
CHARLES W. TOMLINSON		

SUB-COMMITTEE ON TERTIARY

W. ARMSTRONG PRICE (1944), *chairman*, Box 1860, Corpus Christi, Texas

THOMAS L. BAILEY	WAYNE V. JONES	WATSON H. MONROE
MARCUS A. HANNA	GENTRY KIDD	E. A. MURCHISON, JR.
HENRY V. HOWE	TOM MCGLOTHLIN	WARREN B. WEEKS

COMMITTEE ON APPLICATIONS OF GEOLOGY

CAREY CRONEIS (1943), *chairman*, Univ. of Chicago, Chicago, Illinois
HENRY C. CORTES (1944), *vice-chairman, geophysics*, Dallas, Texas
GAYLE SCOTT (1945), *vice-chairman, paleontology*, Fort Worth, Texas

1943	1944	1945
R. M. BARNES	GEORGE S. BUCHANAN	M. M. LEIGHTON
CARROLL E. DOBBIN	WESLEY G. GISH	PAUL H. PRICE
H. S. MCQUEEN	KENNETH K. LANDES	
B. B. WEATHERBY	PAUL WEAVER	

SPECIAL COMMITTEES

COMMITTEE ON COLLEGE CURRICULA IN PETROLEUM GEOLOGY

FREDERIC H. LAHEE, *chairman*, Sun Oil Company, Dallas, Texas

L. T. BARROW	WINTHROP P. HAYNES	JOHN D. MARR
WALTER R. BERGER	K. K. LANDES	E. K. SOPER
HAL P. BYBEE	HENRY A. LEY	W. T. THOM, JR.
IRA H. CRAM	JOHN T. LONSDALE	

NATIONAL SERVICE COMMITTEE

FRITZ L. AURIN, *temporary chairman*, Southland Royalty Company, Fort Worth, Texas
A. RODGER DENISON, *vice-chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma

A. E. BRAINERD	EUGENE HOLMAN	GEORGE D. PUTNAM
IRA H. CRAM	ROBERT F. IMBT	CARLETON D. SPEED, JR.
RONALD K. DEFORD	J. R. LOCKETT	WILLIAM H. SPICE, JR.
M. GORDON GULLEY	PHIL F. MARTYN	B. B. WEATHERBY
K. C. HEALD	FRANK A. MORGAN	W. E. WRATHER
	EDGAR W. OWEN	

DISTINGUISHED LECTURE COMMITTEE

JOHN L. FERGUSON, *chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma

LON D. CARTWRIGHT, JR.	DARSIE A. GREEN	CHARLES E. YAGER
	JOHN W. INKSTER	

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO 12 (DECEMBER, 1942), PP. 1854-1856, 2 FIGS.

MEMORIAL

NOLAN ANTHONY FANGUY
(1916–1942)

Lieutenant Nolan A. Fanguy, United States Army Air Corps, was killed on August 22, 1942, in an airplane accident near Key Field, Meridian, Mississippi.

Lieutenant Fanguy was born at Houma, Louisiana, on January 16, 1916, the son of

Albert T. and Alida Mary Fanguy. He attended school at Houma and graduated from Terrebonne High School in 1933. Before entering college, Fanguy was employed for various periods as camp helper for The Texas Company, as rodman for the Louisiana Highway Commission, and as rodman with a shooting crew for the Barnsdall Oil Company. He entered the Louisiana State University in September, 1936, majored in geology and graduated with the degree of Bachelor of Science in geology in 1940. Fanguy was considered an excellent student by his faculty and a valued friend by his fellow students. He was an active member of the Louisiana Section of the Geological and Mining Society of American Universities and was also active in various other student affairs.

After graduation he was employed by the Shell Oil Company until he resigned to enter the Army as an Aviation Cadet on November 1, 1941. He was elected to associate membership in the Association on October 23, 1940, sponsored by Chalmer J. Roy, James H. McGuirt, and Harold N. Fisk.

Fanguy received his aviation training at Maxwell Field, Alabama, and at Moody Field, Georgia, receiving his wings at the latter on July 3, 1942. He was transferred to Key Field, Meridian, Mississippi, on July 15, 1942, where he was stationed until his death on August 22.

He is survived by his father and mother, one brother, and six sisters, all of Houma, Louisiana.

By his untimely death his family has lost a devoted son and brother; all who knew him have lost a valued friend; and our profession and Association have lost an enthusiastic and promising member.

CHALMER J. ROY

BATON ROUGE, LOUISIANA
November, 1942

MAREE CUMMINGS
(1904–1942)

Our members and a host of other friends were greatly shocked at the untimely death of Miss Maree Cummings in Tulsa, Oklahoma, June 25, 1942, following an appendectomy. Miss Cummings at the time of her death was secretary to Mr. Hull and office manager at the Tulsa Headquarters of the Association.

Born in Shawnee, Oklahoma, December 1, 1904, she attended grade school and Shawnee High School, later moving to Tulsa where she completed business school. During her childhood and school days she was active in sports and attracted much admiration in dramatics.

To have known Maree Cummings over a period of some sixteen years has been the privilege of the writer. She was an able and efficient business associate in the conduct of Association affairs, and a good friend; the possessor of a rare combination of those fine qualities which make the real people on this earth. She had a radiant sense of optimism, always looking on the bright side of life and everything associated with it. Even though she might have had worry and sadness in her life, her happy thoughts and bright disposition seemed ever constant. She was at all times giving charity, help, and sympathy wherever it was needed and had she been in a position to receive or need like consideration, it would have been her wish that no one should ever know.

She loved life and enjoyed it as very few people can and it was her philosophy that if there were any who did not understand her—"it is not their business to even try." Conversely, she knew people and human character and always seemed to be proud of the good qualities in others. If she had knowledge or gossip uncomplimentary to any man or woman, she was just big enough to forget it and not bother about passing it along.

As an ambassador of good will within the Association and for the Association she was outstanding. There are hundreds of us and many others outside of the Association who knew Miss Cummings well enough to share in the drafting of this eulogy and who could add many fine things to it with a feeling of sincere appreciation.

MAREE CUMMINGS

Maree Cummings will live in the memory of her friends and associates as a brilliant character, an able associate and a loyal friend, true to the spirit of our membership.

We are proud to have known her, to have had her with us.

F. L. AURIN

November, 1942

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 26, NO. 12 (DECEMBER, 1942), PP. 1857-1866

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

A. C. TESTER has been granted a leave of absence from the State University of Iowa for the duration to accept a commission as captain in the Corps of Engineers.

VERNER E. JONES is a first lieutenant with the 15th Air Depot Group, Duncan Field, Texas.

EDWARD E. REIGLE is a flight instructor of Army glider pilots in the Army Air Corps, Ector County Aerial Service, Odessa, Texas.

HARRY W. ANISGARD, formerly with The Texas Petroleum Company in Caracas, Venezuela, may now be addressed at 503 West 124th Street, New York City.

GARTH W. CAYLOR, Shell Oil Company, Inc., has moved from Evansville, Indiana, to Centralia, Illinois.

JOHN C. MAXWELL has been commissioned an ensign in the U. S. Naval Reserve, temporarily assigned to Fort Schuyler, The Bronx, New York.

THEODORE GLEN FISHER, geologist for the Cities Service Oil Company for nine years, has been commissioned a lieutenant (j.g.) in the Naval Reserve.

Lieutenant (j.g.) ROBERT L. CLARKE is with the Fighter Director School, 14th Naval District, Pearl Harbor, T. H.

JAMES W. NANCE has returned from Caracas, Venezuela, and may be addressed at 608 North Hudson, Altus, Oklahoma.

C. J. KNUTSON is with Ford Bacon & Davis, Inc., 39 Broadway, New York City, assigned, as a planning engineer, to the Louisville, Kentucky, butadiene plant.

DONALD B. EICHER can be addressed in care of the Dominican Seaboard Oil Company, Apartado 111, Ciudad Trujillo, Dominican Republic, following his return from Cairo, Egypt.

GEOFFREY W. CRICKMAY is no longer with the War Production Board as industrial analyst as he has been commissioned a lieutenant in the U. S. Naval Reserve, temporarily assigned to the U. S. Bureau of Ships in Washington, D. C.

ARNOLD C. DAHL is a first lieutenant stationed at Camp Claiborne, Louisiana.

F. E. VANDENBERG, formerly with the Colombian Petroleum Company at Cucuta, Colombia, is a lieutenant in the U. S. Army.

FRANK W. MICHAUX is a lieutenant in the U. S. Naval Reserve stationed at Treasure Island, San Francisco, California.

F. L. AURIN, Association president, addressed the Pacific Section at Los Angeles, November 14, on the subject, "Applications of Geology in the War Effort."

JOHN L. RICH, department of geology at the University of Cincinnati and author of the recent book, *The Face of South America* (An Aerial Traverse), spoke before the Indi-

ana-Kentucky Geological Society at Evansville, Indiana, on November 13 on the subject, "Physiography and Structure of the Western Andes."

A. H. WADSWORTH, JR., has moved from Midland, Texas to 2000 Austin Street, Bay City, Texas. He has joined the United States Geological Survey and is engaged in the exploration for lead and zinc in eastern Nevada.

JOHN R. FANSHAWE, II, has accepted a position as district geologist in the Office of Petroleum Coördinator for War, with headquarters at District 4, Denver, Colorado.

PARKE A. DICKEY has resigned his position as senior geologist in charge of oil and gas work with the Pennsylvania Topographic Survey at Pleasantville, Pennsylvania, and has accepted the position of chief geologist of the Forest Oil Company at Bradford, Pennsylvania.

DICK TEEL is a lieutenant stationed at Protu Army Air Base, Colorado Springs, Colorado, with the 11th Photo Mapping Squadron.

LAURENCE BRUNDALL, who has been with the Shell Oil Company, Inc., the past six years as research geologist, has accepted a commission as ensign in the Navy.

KENDALL E. BORN, of the Tennessee State Geological Survey, talked on "The Pre-Cretaceous Rocks of the Northern Part of the Mississippi Embayment," before the Tulsa Geological Society, Tulsa, Oklahoma, November 9, and at the November 17 meeting of the Shreveport Geological Society, Shreveport, Louisiana.

ANTHONY FOLGER, for many years geologist with the Gulf Oil Corporation, became a consulting geologist, October 1, with the Auto Ordnance Corporation in Wichita, Kansas.

The Wagner Free Institute of Science at Philadelphia has recently published two installments of the North American Devonian fossil catalogue sponsored by the Paleontological Society. C. C. BRANSON is the author of the section on the Conocardiidae, and A. S. WARTHIN, JR., of that on the Leperditacea.

TRACY GILLETTE, recently with the Illinois Geological Survey Division, died November 9. His home address was 763 Helendale Road, Rochester, New York.

JOHN D. LATOUCHE entered the Canadian Army on July 8, 1941 and is now assigned, as a first lieutenant, to the 3d Battalion, Royal Canadian Engineers, Base Post Office, Canadian Army Overseas.

JOHN T. LONSDALE has been ordered to active duty under his commission of lieutenant colonel in the Officers Reserve Corps. Correspondence may be addressed to 1910 Fortieth Street, Des Moines, Iowa.

MEMBERS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS SERVING IN THE ARMED FORCES OF THE UNITED STATES AND ALLIED COUNTRIES

(Supplementary List)*

Name	*Home Address*	*Rank*	*Branch of Service*
Adams, Robert Wiley	Box 664 Reseda, Calif.		U.S. Navy
Ballard, James L.	602 Driscoll Bldg. Corpus Christi, Tex.	Lt.	U.S. Marine Corps

* Original list in October, 1942 Bulletin.

Bosco, Francis N.	2166 S. Washington Denver, Colo.	Sgt.	U.S. Army
Briggs, Colver R.	533 S. Arden Blvd. Los Angeles, Calif.	Cadet	Army Air Corps
Brown, Augustus Bart	Naval Section Base Savannah, Ga.	Ens.	U.S. Navy
Brundall, Laurence	1701 Rosario Laredo, Tex.	Ens.	U.S. Navy
Clark, J. T.	1640 New Hampshire Lawrence, Kan.	Ens.	U.S. Navy
Conley, Jack N.	1444 S. Carson Tulsa, Okla.	Pvt.	U.S. Army
Cooley, Ralph S.	c/o George P. Livermore, Inc. Lubbock, Tex.	Lt.	U.S. Navy
Cox, Harris	Navy Dept. Washington, D.C.	Lt.	U.S. Navy
Crickmay, Geoffrey W.	48 Hubinger St. New Haven, Conn.	Lt.	U.S. Navy
Cross, Charles Mumaw	1900 Adeline Dr. Burlingame, Calif.		Armored Force
Dahl, Arnold C.	337 S. Rutan Wichita, Kan.	Lt.	Corps of Engineers
Davis, Gene O.	9715 E. Sixteenth St. Independence, Mo.		Army Air Corps
Diemer, Raymond A.	205 Roosevelt Ave. Robinson, Ill.		U.S. Army
Dunlap, George E.	1636 S. Florence Pl. Tulsa, Okla.	Ens.	U.S. Navy
Engel, Noel W.	122 Sherman Ave. Hamilton, Ohio	Lt.	U.S. Navy
Fisher, Theodore Glen	400 S. Cedar Newkirk, Okla.	Lt.	U.S. Navy
Fowler, Henry Florey	Box 215 Mt. Pleasant, Tex.	Ens.	U.S. Navy
Hagen, Cecil Vernon	633 N. Nelson St. Arlington, Va.	Lt.	U.S. Navy
Hake, Benjamin Franklin	561 E. Thirty-seventh Indianapolis, Ind.	Major	Corps of Engineers
Herd, John Harvey	Standard Oil Co. of Texas Midland, Tex.		Army Air Corps
Howard, Douglas D.	906 Normal Ave. Natchitoches, La.		U.S. Army
Huntley, Louis Guy	Victoria Road Donna, Tex.	Ens.	Naval Air Corps
Hussey, Keith M.	1404 W. Kentucky Midland, Tex.	Lt.	Army Air Corps
Jones, Verner E.	1506 S. Race St. Urbana, Ill.	Lt.	Army Air Corps
LaTouche, John D.	Box 2831 Beaumont, Tex.	Lt.	R.C. Army Engineers
Lee, Herbert V.	Room 627, Roney Plaza Hotel Miami Beach, Fla.	Lt.	U.S. Army
Lewis, William D.	1240 Arden Rd. Pasadena, Calif.	Ens.	U.S. Navy
Lock, John H.	210 Farragut Laredo, Tex.		U.S. Marine Corps
Lonsdale, John T.	1910 Fortieth St. Des Moines, Iowa	Lt. Col.	U.S. Army
Maxwell, J. C.	Princeton Univ. Princeton, N.J.	Ens.	U.S. Navy
McIntyre, G. T.	Naval Tng. School, Harvard Univ., Cambridge, Mass.	Lt.	U.S. Navy
Meyer, Ruskin H.	Rt. 2 Anthony, Kan.		U.S. Army

Michaux, Frank W.	3417 Ella Lee Lane Houston, Tex.	Lt.	U.S. Navy
Moore, Raymond C.	Univ. of Kansas Lawrence, Kan.		Corps of Engineers
Oliver, Richard R.	211 Ballston Ave. Scotia, N.Y.	Lt.	Army Air Corps
Pierce, Harold Frederick	1304 S. Indianapolis Tulsa, Okla.	Cadet	U.S. Coast Guard
Price, W. Armstrong	Box 1860 Corpus Christi, Tex.	Capt.	U.S. Army
Reigle, Edward E.	Ector County Aerial Service Odessa, Tex.		Army Air Corps
Robie, R. H.	3909 Huntington St., N.W. Washington, D.C.	Ens.	U.S. Navy
Rogers, Wilbur F.	231 E. Seward St. Seward, Neb.		U.S. Navy
Ronbeck, Arthur C.	Pensacola, Fla.	Cadet	Naval Air Corps
Rukas, Justin M.	1957 Wisteria St. Baton Rouge, La.		U.S. Army
Selover, J. B.	10207 Lakeshore Blvd. Cleveland, Ohio	Lt.	Naval Air Corps
Sherman, Wilbur B.	679 High St. Orville, Calif.	Lt.	Army Air Corps
Tester, A. C.	228 Woolf Ave. Iowa City, Iowa	Capt.	Corps of Engineers
Vandenberg, F. E.	2318 W. Eighth St. Los Angeles, Calif.	Lt.	U.S. Navy
Woodbury, Homer O.	840 Twelfth St. Boulder, Colo.	Ens.	U.S. Navy
Yenne, Keith A.	Box 11 Cambridge, Mass.	Ens.	U.S. Navy

(Additional Supplementary List)

Name	*Home Address*	*Rank*	*Branch of Service*
Bard, Richards J.	Bryn Mawr, Pa.	Major	U.S. Army
Barney, Arthur Y.	Box 873 Charleston, W.Va.	Capt.	Army Air Corps
Barwick, John S.	139 N. Lorraine Wichita, Kan.	Lt.	Army Air Corps
Browne, Richard V.	Box 309 Haifa, Palestine	Lt.	British Army
Buie, Bennett Frank	Warrenton, Va.	Lt.	Corps of Engineers
Corman, Hyman	Plymouth Oil Co. Midland, Tex.		U.S. Army
Downing, Roswell B.	Lane-Wells Co. Tulsa, Okla.	Lt.	Army Air Corps
Edwards, Harold S.	612 S. Grand Lyons, Kan.		U.S. Navy
Gahring, William Ross	Box 520 Shawnee, Okla.	Capt.	U.S. Army
Given, Robert J.	3708 E. Douglas Wichita, Kan.	Capt.	Army Air Corps
Goudy, Lewis W.	936 W. Elm Yukon, Okla.		U.S. Navy
Hotchkiss, Henry	Basrah Petr. Co. Basrah, Iraq	Ens.	U.S. Navy
Johnston, John C.	Box 1099 Shawnee, Okla.	Ens.	U.S. Navy
Jones, Walter B.	Dept. of Conservation Montgomery, Ala.	Lt. Col.	Army Air Corps
Kennedy, Joseph B.	Box 1990 Fort Worth, Tex.	Lt.	U.S. Navy

Lafferty, Robert C.	4007 Staunton Ave. Charleston, W.Va.	Lt.	U.S. Navy
Langham, N. T.	Petr. Devel. (Qatar) via Manama Bahrein Island, Persian Gulf	Lt.	U.S. Army
Melsheimer, Albert H.	Aviation Cadet Detachment Scotts Field, Ill.	Cadet	Army Air Corps
Reeves, Frank W.	2905 Merida Fort Worth, Tex.	Capt.	Army Air Corps
Rogers, Maynard	6039 Oakwood Ave. Cincinnati, Ohio		Army Air Corps
Scott, Wilton E.	Drawer G Hobbs, N.M.		Army Air Corps
Steel, Robert J.	1420 N. Broadway Santa Ana, Calif.		U.S. Army
Teel, Dick	327 Parland Pl. San Antonio, Tex.		Army Air Corps
Ustynik, Edwin F.	Box 90 Rosenberg, Tex.	Pvt.	Corps of Engineers
Vincent, Mordelo L., Jr.	Box 103 Lake Charles, La.	Lt.	Army Air Corps
Wahlstrom, E. A.	Box 1801 Midland, Tex.	Lt.	Naval Air Corps
Whatley, James M.	155 Egan St. Shreveport, La.	Ens.	U.S. Navy
Winzeler, Alvin R.	429 First Natl. Bank Bldg., Wichita, Kan.	Lt.	Army Air Corps

MEMBERS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS EMPLOYED BY THE UNITED STATES AND ALLIED COUNTRIES IN CIVILIAN WORK

(Additional Supplementary List)

Bacon, Charles S., U.S. Geol. Survey, Box 853, Prescott, Ariz.
Bennett, Johnson, B. O. D. Co., Ltd., Qaiyarah, Iraq
Brown, Silas C., U.S. Geol. Survey, Box 408, Lawrence, Kan.
Clark, L. Todd, U.S. Engineer Sub-Office, McKinney, Tex.
Coates, George H., 638 Milam Bldg., San Antonio, Tex.
Dawson, R. J., Production Material Analyst, Office of Petroleum Coordinator for War, Houston, Tex.
Fanshawe, John R., II, Office of Petr. Coordinator for War, 320 First Natl. Bank Bldg., Denver, Colo.
Finch, Elmer H., 143 Mistletoe, San Antonio, Tex.
Greig, Douglas A., Thomas Cook & Sons, Ltd., Berkeley St., Piccadilly, London, 1, England
Henson, F. R. S., Iraq Petr. Co., Kirkuk, Iraq
Keeler, Clifton M., 1716 First Natl. Bank Bldg., Oklahoma City, Okla.
Laves, U. R., Machinery Section Head, Regional Office of Price Administration, Fidelity Bldg., Dallas, Tex.
Maher, John C., U.S. Geol. Survey, Baton Rouge, La.
Reeves, Frank, Office of Petr. Coordinator for War, Oakland, Md.
Spice, William H., Jr., 2101 Alamo Natl. Bldg., San Antonio, Tex.
Taylor, Josiah, Dept. of Terrestrial Magnetism, 5241 Broad Branch Rd., N.W., Washington, D.C.
Trager, Earl A., Bur. of Economic Warfare, Washington, D.C.
Wadsworth, A. H., Jr., U.S. Geol. Survey, Bay City, Tex.
Wellings, F. E., Iraq Petr. Co., Katamon, Jerusalem, Palestine

TWENTY-EIGHTH ANNUAL MEETING, FORT WORTH, TEXAS, APRIL 7–9, 1943

F. L. AURIN[1]
Fort Worth, Texas

The twenty-eighth annual meeting of the American Association of Petroleum Geologists, in conjunction with the Society of Economic Paleontologists and Mineralogists and

[1] Chairman, executive committee.

the Society of Exploration Geophysicists, will be held in Fort Worth, Texas, April 7, 8, and 9, 1943.

The executive committee has delayed the selection of the meeting place and this announcement as long as possible on account of the factors of war and transportation conditions. In making this selection the restrictions on railroad and other means of transportation were kept in mind, and it was thought necessary to consider a place centrally located with respect to the greatest density of our membership. Another factor taken into consideration was that on account of the reduced personnel in the geological departments of the oil companies, many members would be able to be away from their duties only for a short time, and for that reason the number of days for the meeting has been reduced from the usual one week to three days. We realize that most of our members would like to attend this meeting, but may not be able to do so on account of the gasoline and tire rationing program and possible restrictions on other means of transportation; however, you are urged to attend, if possible at all to do so, because this will be one of the most important and serious meetings held in the history of the Association. The Fort Worth Geological Society will be host, and we have been assured that there will be ample hotel accommodations to take care of all those attending the meeting.

As stated, the time for the meeting has been reduced to two days of technical sessions and one day of business meetings and conferences, joint and separate, of the different societies, and the symposiums. In other words, the meeting will be streamlined to devote the entire time to the War Problems: symposium on secondary recoveries and favorable areas for wildcatting, petroleum reserves, Levorsen's research program on "Discovery Thinking," addresses by prominent men on very important subjects, and many other papers or conferences on timely and interesting subjects. No local papers will be presented, except to be read by title for future publication in the *Bulletin*. However, it is planned that abstracts will be included in the program. Abstracts should be sent to A.A.P.G. Headquarters, Box 979, Tulsa, Oklahoma, by March 1, 1943. The S.E.P.M. and the S.E.G. will also have technical sessions during the meeting.

No formal entertainment or field trips are planned.

Our plans are to make this strictly a business meeting and no plans have been made for the entertainment of ladies.

MEMORANDUM OF NATIONAL SERVICE COMMITTEE CHANGES IN PERSONNEL PROCUREMENT REGULATIONS[1]

F. L. AURIN[2]
Fort Worth, Texas

The War Department, as of November 7, 1942, has sent out the following information (excerpts from Circular No. 367).

"1. Pursuant to the instructions of the Secretary of War, a separate officer procurement agency, to be known as the Officer Procurement Service, is established under the Chief of the Administrative Services, Services of Supply. The Officer Procurement Service is authorized to deal direct with the Commanding Generals, Army Ground Forces and Army Air Forces, and chiefs of supply and administrative services and with the Secretary of War's Personnel Board in matters pertaining to the procurement and appointment of officers.

"2. Effective November 4, 1942, appointments in the Army Specialist Corps ceased. Those applications for appointment in the Army Specialist Corps then in process and upon

[1] Manuscript received, November 28, 1942.
[2] Chairman, national service committee.

which final action has not been taken by The Adjutant Genera will be returned immediately to the head of the command or activity recommending t e appointment for reconsideration with a view to possible appointment in an appropriat grade in the Army of the United States.

"8. Pending the revision of AR 605-10, the Officer Procuren nt Service will be guided, in the procurement of officers for the Army of the United Stat , by the policies set forth in this circular. It will procure from qualified individuals office in the numbers required by the Army of the United States to fill positions calling for sp cial qualifications and for other purposes, subject to the following limitations. No perso will be recommended or appointed direct from civil life, except as provided in 9 and 10 elow.

a. Who is classified by Selective Service as 1-A-O, 1-B-O, -E, or IV-E-LS;
b. Who has been notified by his Selective Service Board of is call for induction;
c. Who has been deferred by his Selective Service Board in rder to enable him to attempt to obtain a commission;
d. If the proposed duty can be as effectively performed by a ailable civilian personnel;
e. Unless he has a civilian training and experience for the articular position beyond that normally provided at officer candidate schools;
f. Who is under 35 years of age at the date of appointment and is without prior commissioned service, unless classified by Selective Service s Class 4-F on account of physical disability;
g. Who is over 34 years of age but under 45 years of age a the date of appointment and is without prior commissioned service, if he is classified (or apparently classifiable, if unclassified) by Selective Service as Class 1-A or Class 2;
h. Who is an employee of any department of the Federal Government other than the Army Specialist Corps, unless his responsible executive has executed a written consent to his solicitation for appointment prior to such solicitation and a written release from his civilian employment.

"9. Exceptions to the above provisions of paragraph 8f and g may be made in the cases where there is a critical need for the services of a particular specially qualified individual or where an individual is within a scarce category of specialized skill in which not enough trained men to fill the requirements of the armed forces are available at the time required. Scarce categories will be determined from time to time.

"10. A former commissioned officer of any component of the Army of the United States, of the Navy, or of the Marine Corps whose prior services were terminated under honorable circumstances may be recommended for and appointed to a position . . . "

In commenting on these regulations with reference to qualified interpreters of aerial photographs of the Army Air Corps, you will note that the minimum age has been raised to 35 except for those who have held a commission in the past, and that they have entirely eliminated the possibility for commissioning those in draft Classes 1 and 2. In the case of those about to be inducted into the service, your attention is again directed to information furnished on page 1695 of the October *Bulletin*.

We have been informed that the Marine Corps will be interested in applicants for commissions in that branch of service for ground work. The applicant must be between the ages of 22 and 42. The list of qualified applicants does not specifically mention geologists, but mining engineers are indicated. This service will entail foreign work and preference will be given to those who have had foreign service and can speak either Javanese or Malayan. Those interested and qualified for this work should contact the nearest Procurement Office of the Marine Corps for further details and information.

You realize that regulations are constantly changing in the Armed Forces and that by the time you read this article other changes may have been made in any of these regulations and requirements.

PROGRESS REPORT OF DISTINGUISHED LECTURE COMMITTEE

JOHN L. FERGUSON
Tulsa, Oklahoma

Under the auspices of the distinguished lecture committee three speakers have been brought before certain of the affiliated societies of the Association during November and December, 1942.

The first speaker was Kendall E. Born, associate geologist of the Tennessee Division of Geology, who discussed "The Pre-Cretaceous Rocks in the Northern Part of the Mississippian Embayment" before the following societies.

November	9	Tulsa Geological Society at Tulsa
"	11	Oklahoma City and Shawnee Geological societies at Oklahoma City
"	12	Fort Worth Geological Society at Fort Worth
"	13	Houston Geological Society at Houston
"	16	South Louisiana Geological Society at Lake Charles
"	17	Shreveport Geological Society at Shreveport
"	18	Mississippi Geological Society at Jackson
"	19	New Orleans Geological Society at New Orleans

Born discussed "History of Oil and Gas Exploration in Tennessee" before the Kansas Geological Society, November 10, at Wichita, Kansas.

The second speaker was Carey Croneis, professor of geology at the the University of Chicago who delivered an address on "Geological Warfare" to the following societies.

November	27	Illinois Geological Society at Centralia
"	28	Kansas Geological Society at Wichita
"	30	Tulsa Geological Society at Tulsa
December	1	Dallas Petroleum Geologists at Dallas
"	1	Fort Worth Geological Society at Fort Worth
"	2	West Texas Geological Society at Midland
"	3	South Texas Geological Society at San Antonio
"	4	Houston Geological Society at Houston
"	5	Shreveport Geological Society at Shreveport

The third lecture tour was undertaken by S. H. Knight, head of the department of geology, University of Wyoming, who gave a series of lectures illustrated with his notable chalk drawings to the following societies.

December	7	Kansas Geological Society at Wichita
"	8	Oklahoma City and Shawnee Geological societies at Oklahoma City
"	9	Tulsa Geological Society at Tulsa
"	10	Dallas Petroleum Geologists at Dallas
"	11	Fort Worth Geological Society at Fort Worth
"	12	West Texas Geological Society at Midland
"	14	North Texas Geological Society at Wichita Falls
"	16	Panhandle Geological Society at Amarillo

Knight's lecture on "Physical Evolution of the Rocky Mountains" was given at Dallas, Midland, Wichita Falls, and Amarillo; on "The Genesis of the Late Paleozoic Sediments of Southeastern Wyoming" at Tulsa, Oklahoma City, and Fort Worth; on "The Tertiary History of the Wyoming Basin" at Wichita, Kansas.

The next speaker is expected to be Lewis B. Kellum, director of the Museum of Paleontology at the University of Michigan who will speak on "The Geologic History of North-Central Mexico and Its Bearing on Petroleum Exploration." This lecture tour is planned for late in January.

H. H. (BUD) ARNOLD, for several years district geologist with the Texas Company at Tulsa, Oklahoma, has been promoted from the rank of captain to that of major as a result of action in the capture of Oran, Africa, according to recent dispatches.

CHARLES SCHUCHERT, honorary member of the Association, professor emeritus of paleontology in Yale University, and author of many books on geology, died at New Haven, Connecticut, November 20, at the age of 84 years.

New officers of the Pacific Section of the Association, elected for 1943, are: president, MAX L. KRUEGER, Union Oil Company of California, and secretary-treasurer, RICHARD TEN EYCK, Continental Oil Company, Los Angeles.

EUGENE HOLMAN has been elected a vice-president of the Standard Oil Company of New Jersey.

BAILEY WILLIS, of Stanford University, is completing the revision of the Geological Map of North America. Under grants of $4,250 from the Geological Society of America, $1,000 from the American Philosophical Society and $1,000 from the American Association of Petroleum Geologists, and with the editorial supervision of GEORGE W. STOSE, it has been entirely redrawn.

EARL A. TRAGER is chief of the Mining Economics Section, Mining Division, War Production Board, Washington, D. C. WILBUR A. NELSON is director of the division.

BERNARD A. RAY, geologist with the Tide Water Associated Oil Company at Midland, Texas, for several years, has resigned to enter the consulting field. Ray is vice-president of the West Texas Geological Society.

JOHN R. SUMAN, vice-president of the Humble Oil and Refining Company, Houston, Texas, has been awarded the Anthony F. Lucas gold medal for 1943, by the American Institute of Mining and Metallurgical Engineers, for his "distinguished achievement in improving the technique and practice of producing petroleum."

CLAUDE E. ZOBELL, of the Scripps Institution of Oceanography, La Jolla, California, addressed the Houston Geological Society, November 19, on "The Importance of Micro-Organisms as Geological Agents."

CLAUDE ROARK, of Tulsa, Oklahoma, recently stationed at Honda, Texas, has been commissioned a 2d lieutenant as aerial observer navigator in the Army Air Corps.

KENNETH ALLEN JOHNSTON, formerly of Boulder, Colorado, and of recent years a resident of Los Angeles, California, passed away in the latter city on November 13, after a lingering illness of several years.

ROBERT B. CAMPBELL, consulting geologist of Tampa, Florida, has been elected president of the Florida Academy of Science.

JOHN P. SMOOTS, of Cleveland, Ohio, in charge of production for the Standard Oil Company of Ohio, has been appointed manager of the exploration and geological department.

ROBERT R. THOMPSON, chief geologist for the Danciger Oil and Refineries, Inc., has resigned to become chief geologist for the Snowden and McSweeney Company, Fort Worth, Texas.

PAUL L. APPLIN, for many years consulting geologist at Fort Worth, has been appointed chief geologist for the Danciger Oil and Refineries, Inc.

JOHN W. FLUDE, 561 Shackamaxon Drive, Westfield, New Jersey, has been employed as a civilian physicist by the Bureau of Ordnance, U. S. Navy.

Effective December 1, 1942, WALLACE E. PRATT, since 1937 a member of the board of directors and of the executive committee of the Standard Oil Company (New Jersey), was elected to the position of vice-president of that company.

EDWIN F. USTYNIK is with the Engineer Replacement Training Center at Fort Leonard Wood, Missouri.

ALBERT H. MELSHEIMER is a cadet with the Air Corps, located at Scotts Field, Illinois.

CLAUDE B. NOLTE, petroleum engineer, is in the fluid dynamics department of The Fluor Corporation at Los Angeles, California, designing aviation gasoline, toluene and butadiene plants.

I. G. SOHN may be addressed at South Strafford, Vermont, where he is stationed as a junior geologist on a U. S. Geological Survey strategic mineral project.

LOUIS W. GOUDY is an apprentice seaman in training at Chicago. His permanent address is 936 West Elm, Yukon, Oklahoma.

M. M. KORNFELD is in the A.A.F., located at the 3d Photo Intelligence Detachment, Bolling Field, Washington, D. C.

FRANK BUTTRAM, geologist of Oklahoma City, was re-elected for a fourth term as president of the Independent Petroleum Association of America at the annual meeting of the directors. C. E. BUCHNER of Tulsa, Oklahoma, was elected executive manager.

RUSSELL V. JOHNSON, 913 Lancaster Building, Calgary, Alberta, recently returned from the Gaspé Peninsula in eastern Quebec, where he was doing petroleum geological work.

ROY E. DICKERSON, 1305 North Adams Street, Arlington, Virginia, recently succeeded WILLIAM B. HEROY in the petroleum division, technical branch, of the Board of Economic Warfare at Washington. Dickerson has been in foreign petroleum geological work for 24 years.

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ERRATA

Page 275, paragraph 2, last line. "Million" should be *thousand.*
Page 852, last line. "Eventually" should be *promptly.*
Page 854, line 2. "1 million" should be *3 million.*

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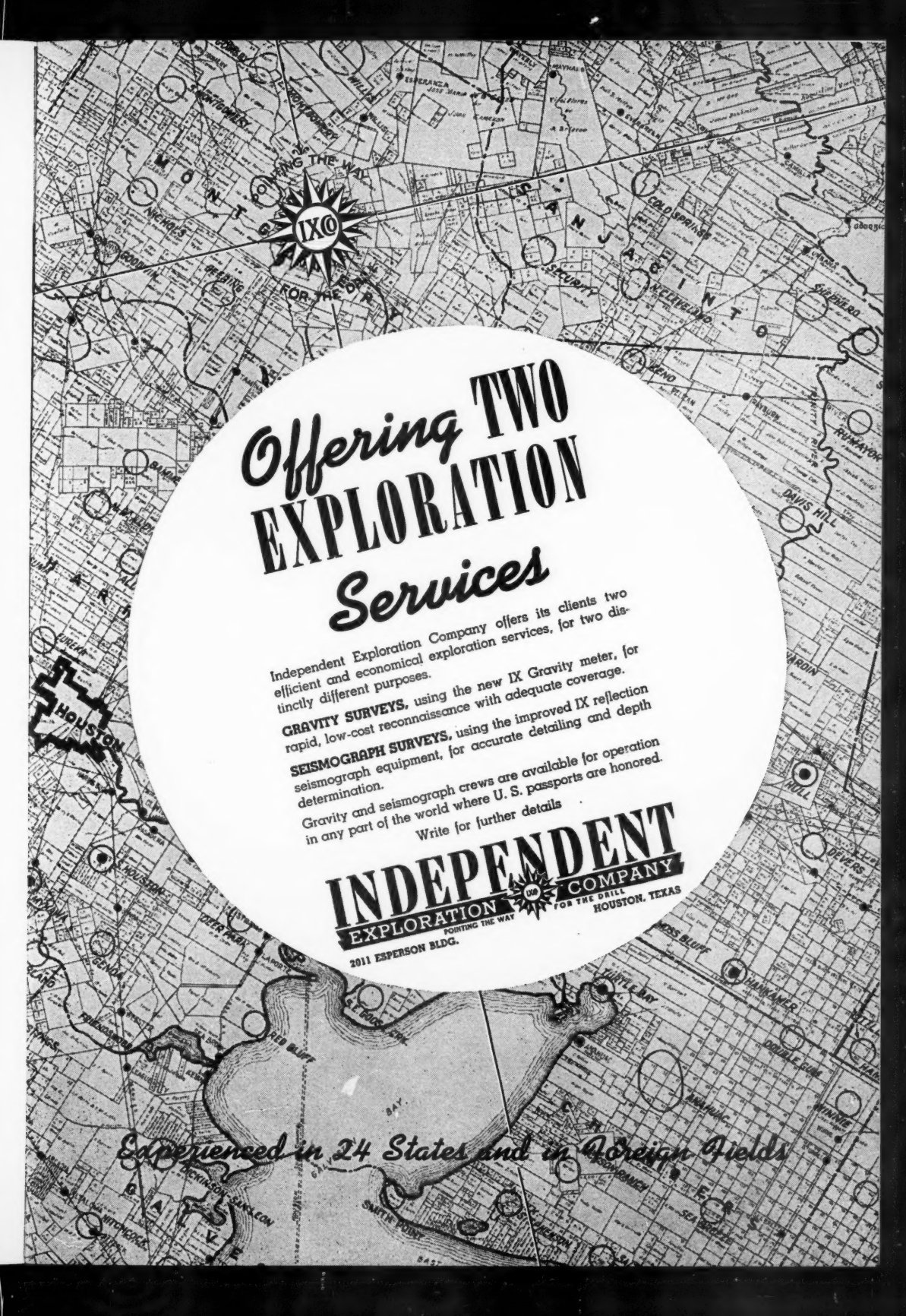

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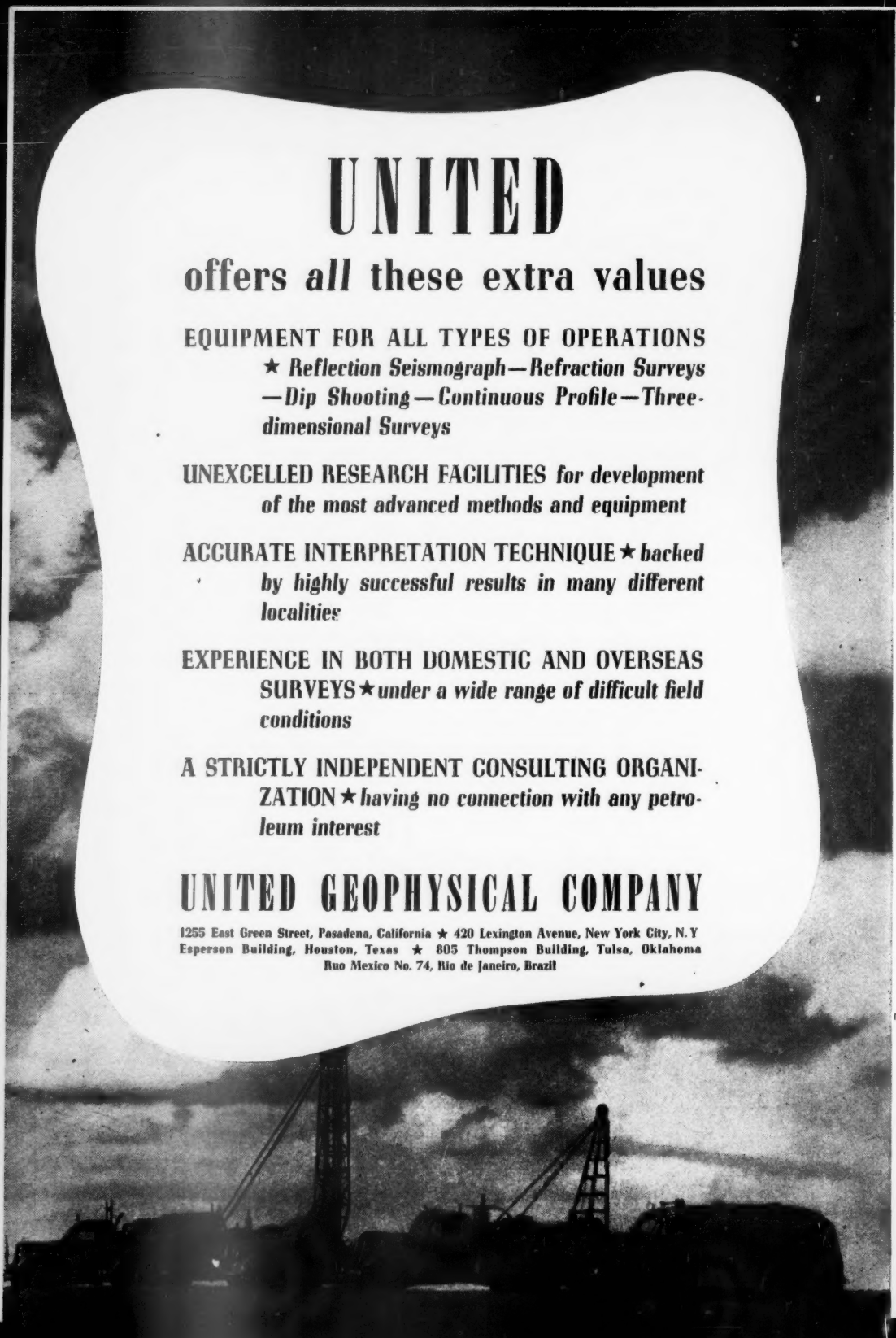
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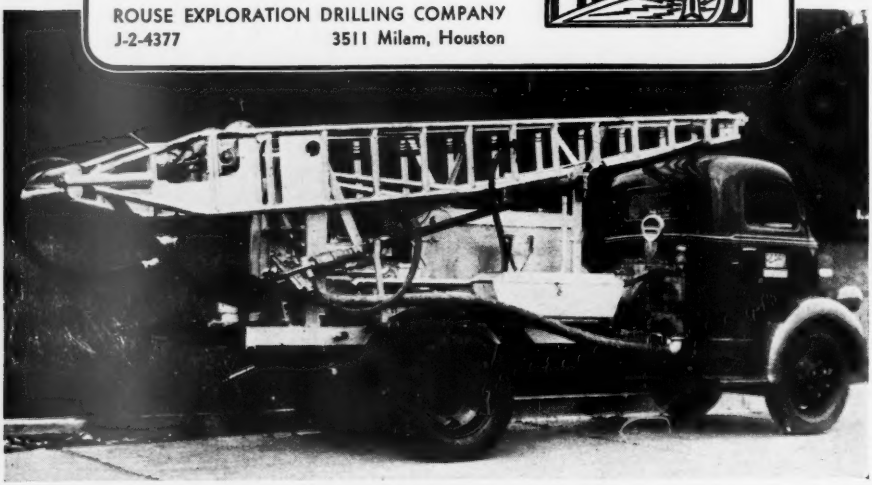

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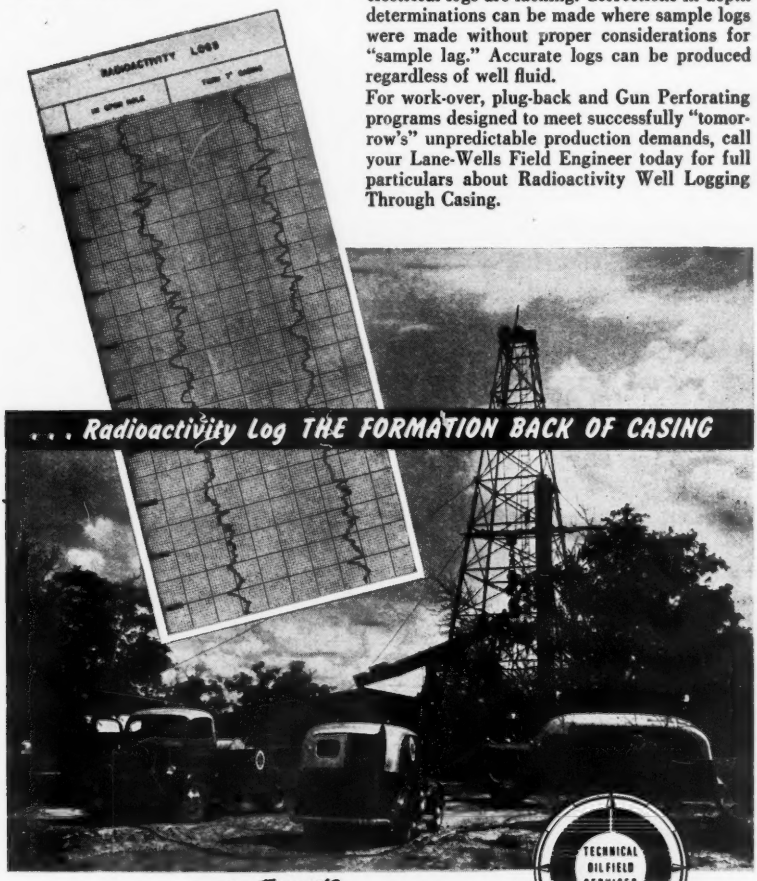

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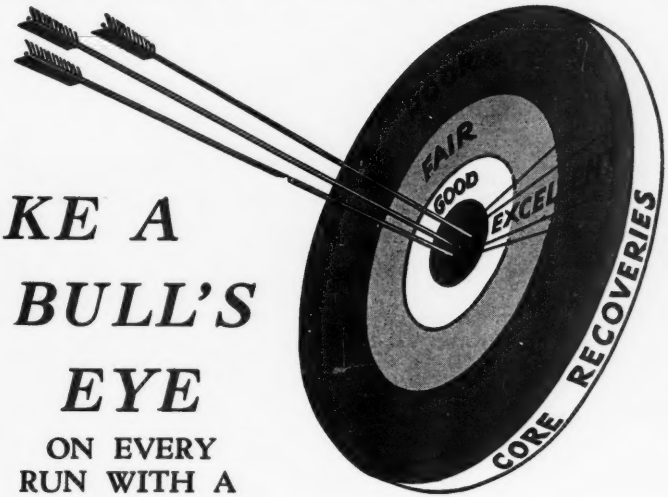

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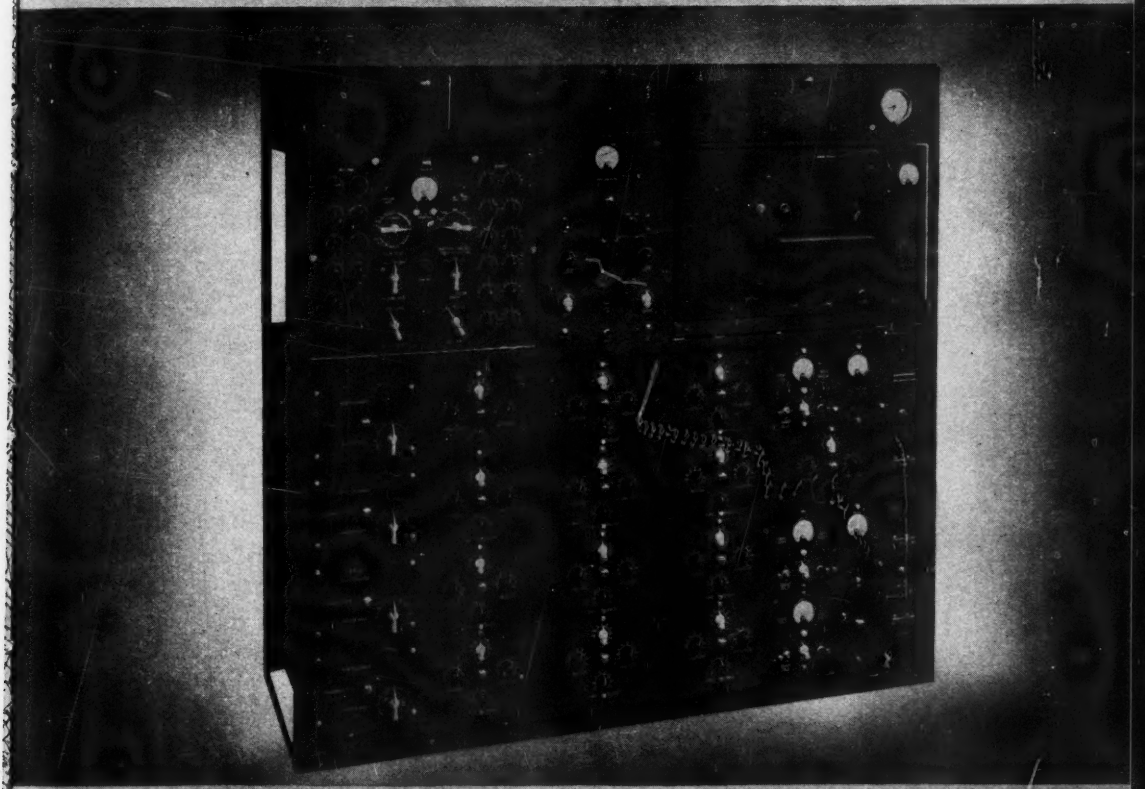

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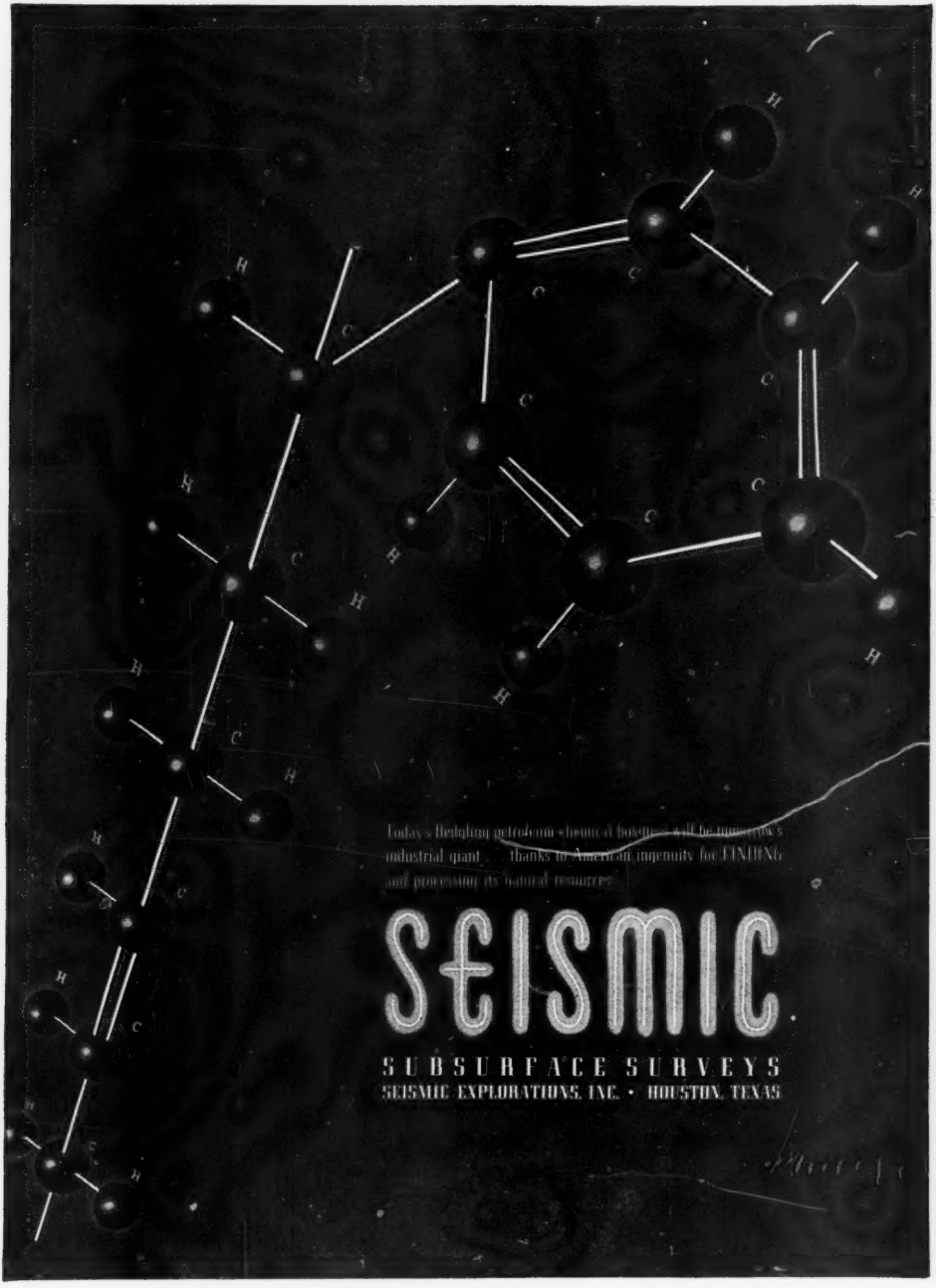
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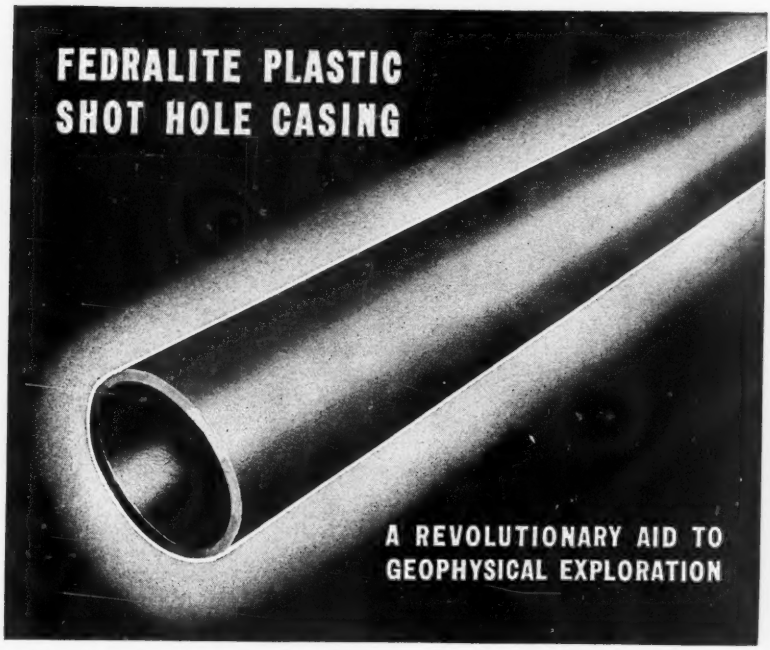

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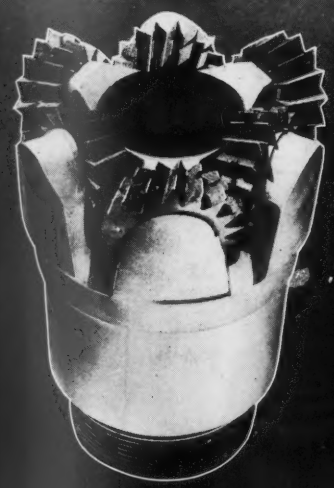

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